UNCLASSIFIED

AD NUMBER	
AD305681	
CLASSIFICATION CHANGES	
TO:	**UNCLASSIFIED**
FROM:	**CONFIDENTIAL**
LIMITATION CHANGES	
TO: **Approved for public release; distribution is unlimited. Document partially illegible.**	
FROM: **Distribution authorized to U.S. Gov't. agencies and their contractors; Administrative/Operational Use; 22 JAN 1959. Other requests shall be referred to Naval Ordnance System Command, Washington, DC 20360. Document partially illegible.**	
AUTHORITY	
31 JAN 1971, dodd 5200.10 gp-4; usnol ltr, 29 aug 1974	

THIS PAGE IS UNCLASSIFIED

~~CONFIDENTIAL~~

AD 305681

Armed Services Technical Information Agency

ARLINGTON HALL STATION
ARLINGTON 12 VIRGINIA

FOR
MICRO-CARD
CONTROL ONLY

1 OF 2

~~CONFIDENTIAL~~

CONFIDENTIAL

NAVORD REPORT 5751

TECHNICAL EVALUATION OF THE ROCKET FUZE MK 181 MOD 0 AND 1 (T – 2023E1) (U)

22 JANUARY 1959

DEPARTMENT OF THE NAVY
NAVAL ORDNANCE LABORATORY

U. S. NAVAL ORDNANCE LABORATORY

WHITE OAK, MARYLAND

CONFIDENTIAL

CONFIDENTIAL
NAVORD REPORT 5751

FC

TECHNICAL EVALUATION OF THE ROCKET FUZE MK 181 MOD 0 AND 1 (T-2023E1)

Prepared by

J. P. Adams
E. W. Blevins
P. B. Morgan

ABSTRACT: This report covers only that portion of the evaluation conducted by the Naval Ordnance Laboratory on the Fuzes T-2023E1, Mk 181-0, and Mk 181-1. The Naval Ordnance Test Station portion of the evaluation is covered in the NOTS Technical Progress Report No. 865. The three fuzes discussed are basically the same fuze. The T-2023E1 was an Army manufactured fuze, and was procured for the initial evaluation. The Mk 181-0 is the same fuze manufactured under Navy contract with Navy drawings. The Mk 181-1 is the new modification, the difference being in the escapement mechanism.

Results of laboratory measurements, environmental, arming, and explosive tests are reported. Deficiencies uncovered during the evaluation are discussed. On the basis of information obtained at NOTS and NOL the fuzes are considered to be adequately safe, reliable, and effective for use in an anti-tank rocket.

U. S. NAVAL ORDNANCE LABORATORY
White Oak, Silver Spring, Maryland

NAVORD REPORT 5751 22 January 1959

The Naval Ordnance Test Station was directed by the Bureau of Ordnance to prove-in the Fuze T-2023E1 (subsequently designated Mk 181) and its appropriate head for Navy and Marine Corps use. In accordance with the technical direction responsibilities exercised by the Naval Ordnance Laboratory on various aircraft rocket fuze programs, appropriate action was taken in regard to the evaluation of the T-2023E1, Mk 181-0, and later the Mk 181-1. A joint program of laboratory and field evaluation was agreed upon by NOL and NOTS with the majority of the tests being performed at NOTS.

The tests conducted by NOL under Task NOL-A2b-11-1 are herein reported.

The conclusions and observations presented are those of the Air and Surface Evaluation Department.

Reference (a) reported the results of the evaluation of the Mk 181-0 and reference (b) released the Mk 181-0 and 181-1 to production.

M. A. PETERSON
Captain, USN
Commander

A. J. Wadman

A. J. WADMAN, Chief
Air and Surface
Evaluation Department

ACKNOWLEDGMENT

This report, to a large extent, is a compilation of the results of work conducted by personnel of The Air and Surface Evaluation Department and The Environmental Evaluation Department of the Naval Ordnance Laboratory. All contributions to this project are hereby generally and gratefully acknowledged.

REFERENCES

(a) NOL Conf ltr NP/NOL/X1-1 (11982) 10 Jan 1955 to BUORD
(b) NOL Conf ltr NP/NOL/X1-1 (13519) 14 July 1955 to BUORD
(c) Picatinny Arsenal Technical Report 1783 pg. 1554
(d) NOTS Report No. 865 (TPR 78)
(e) Picatinny Arsenal Conf ltr of 22 Oct 1954 K. Wong/bjw/ 6245 to NOL (NOL file NP/NOL/X1-1 (11469)

CONTENTS

ILLUSTRATIONS

TECHNICAL EVALUATION OF THE ROCKET FUZE MK 181 MOD 0 AND 1 (T2023E1)

INTRODUCTION

1. The Rocket Fuze T-2023E1 is a point-initiating, base detonating fuze that provides delayed arming by incorporating a NOTS model 502A Arming Mechanism.

2. The fuze (except for the 502A mechanism) was designed and developed by Picatinny Arsenal for use in the 2.75 HEAT (high explosive anti-tank) Head T-2016E1. The fuze and head combination are used with the FFAR (Mighty Mouse) rocket as a shaped-charge, armor piercing weapon. It was released by OCO for Air Force use and because of the similarity of many parts of this fuze to the Navy Mk 176, the Bureau of Ordnance became the purchasing agent. Army Ordnance drawings were converted to BUORD drawings. Existing Army specifications were converted to BUORD Requirements and Test Procedures and NAVORD OCD's were prepared. The T-2023E1 fuze was then designated as the Rocket Fuze Mk 181 Mod 0 (Figure 1) and the head became the 2.75 Head Mk 5. The fuze then went into production by Elgin National Watch Company and Bulova Watch Company for delivery to the Air Force.

3. The Naval Ordnance Test Station, Inyokern, California was directed by the Bureau of Ordnance to prove-in the fuze (T-2023E1) and its associated HEAT Head (T-2016E1) for Navy and Marine Corps use.

4. The Naval Ordnance Laboratory under its responsibility for technical direction of fuze development was directed to take appropriate action in regard to evaluation tests for the fuze. By mutual agreement, NOL and NOTS formulated an extensive evaluation program which was to be conducted primarily by the Naval Ordnance Test Station. However, because NOTS did not have certain specialized test equipment, some of the laboratory tests were conducted at NOL.

5. The evaluation of the T-2023E1 and Mk 181-0 was completed and the Bureau of Ordnance informed of the results by reference (a). The fuze was judged to be a reliable and effective fuze for anti-tank use. Certain areas of marginal design such as questionable long-term storage life, possibility of assembly in the armed position, and defects in the acceptance tests were disclosed.

6. At the time of the completion of the evaluation of the Mk 181 Mod 0, the Mk 181 Mod 1 had been developed and was under consideration for release. The only difference in the two Mods is the substitution of the balanced verge escapement in the Mod 1 for the unbalanced escapement of the Mod 0. The reason for the development of the Mod 1 was to eliminate certain testing difficulties in the ballistic acceptance tests on the guided launcher system. In addition, the balanced verge escapement is more economical and parallels the trend in other fuzes of this family such as the Mk 176-1, Mk 178-2, and the Mk 184, which use the balanced verge escapement. It was judged that the only possible effect of this modification on the fuze performance would be a change in the distribution of the arming distance.

LABORATORY EVALUATION TESTS

7. Conformance to Specifications and Drawings and Engineering Study. Ten inert samples of the Mk 181 Mod 0 from the preliminary lot of Elgin National Watch Company were checked for conformance to specifications for inert fuzes. Fifteen inert T-2023E1 fuzes obtained from Picatinny Arsenal, which were representative of the original evaluation lot, were checked for conformance to drawings and to conformance to specifications for inert fuzes. (Conformance to specifications included transportation vibration tests and centrifuge arming tests.) Samples of the T-2023E1 were disassembled and the dimensions considered essential to the functioning of the fuze were measured. A dimensional study of the drawings was made to determine the possibility of misfits of mating components using maximum and minimum tolerances. The most serious result of this series of tests was the failure of the locking detent to operate when the detent hole was brought into alignment by a rotor action test. This difficulty was more prevalent in the T-2023E1 fuzes (10% in Mk 181 and 66% in the T-2023E1). It appeared that during the course of testing, the plating wore off the detent and the black oxide finish wore off the lock spring. This condition allowed oxidation to take place between the detent and the outer plate and between the detent and the lock spring (Figure 2). NOTS' dimensional study also reported detents unplated or containing bare spots in the T-2023E1 fuze. It was judged that if the components of this mechanism are made within the allowable tolerances specified on the drawings, proper fits between mating parts should be assured, and the mechanical aspects of this fuze should function properly.

The Ordnance Classification of Defects for the Mk 181 Mod 0 and Mod 1 were reviewed and they appeared to be adequate and thorough.

8. NOL 24" Jumble Test. Five fully loaded T-2023E1 fuzes were subjected to the NOL 24" Jumble Test. A pre-breakdown inspection showed the fuzes were not externally affected. The breakdown inspection revealed the fuzes still in the unarmed position and still apparently operable. Further inspection revealed some powdering of the RDX on the open ends of the booster cup and lead-in cup. This condition, although undesirable, was considered not to be unsafe. It is judged that the fuze passed this test.

9. NOL 40' Guided Drop Test. Five loaded T-2023E1 fuzes were allocated to the 40' Guided Drop. They were tested one in each of five orientations ranging from nose up to nose down in 45-degree increments. The breakdown inspection disclosed that all the fuzes had remained in the unarmed position. The fuzes suffered some internal damage to the mechanism. Three of the five RDX rotor leads were protruding approximately 1/32" from the rotor. In two of the fuzes,the RDX broke up slightly in the lead-in and booster cup. The damage suffered by this test was considered not to be pertinent from the safety standpoint. With the exception of the aforementioned conditions, the explosive components appeared to be normal and no degree of unsafety was observed.

10. MIL-STD-304 Temperature and Humidity Test.

a. The MIL-STD-304 Temperature and Humidity Test was applied to fourteen fuzes from the preliminary lots of the Mk 181 Mod 0 Fuze. Of these samples six were of Elgin National Watch manufacture and the remaining eight were made by the Bulova Watch Company. The six Elgin fuzes were unsealed between the booster magazine and the fuze body. The Bulova samples were completely sealed. Prior to MIL-STD-304 all the fuzes were subjected to a leak test and then leak tested again after the MIL-STD-304 test. Following the final leak testing, the test samples were broken down and inspected for damage to internal parts. Leak test procedures and test results are described herein.

b. Figure 3 is a photograph of the equipment used in performing leak tests of the fuze. The brass bomb, A, was designed specifically for leak testing the Fuze Mk 181.

The valves B and C are standard type vacuum valves of the bellows type. The U-bend in the copper tubing, shown as D, was immersed in an acetone-dry ice mixture and acted as a cold trap. The line E was attached directly to a Cenco-Megavac type vacuum pump. F is a thermocouple vacuum gauge, Model 501, manufactured by the National Research Corporation. The Vacuum Gauge control G, shows the a.c. input in amperes, the thermocouple output in d.c. microamperes, and the pressure of the test system in microns. Input current for the thermocouple gauge used in these tests was 0.62 a.c. amperes. The test bomb itself which is shown in Figure 4, was so designed as to leave as small a volume as possible after the fuze had been placed in it for testing. The top of the bomb was grooved to receive a rubber O-ring on which a steel lid nested. The pressure of the atmosphere on the lid during the test formed a seal. The Bourdon tube gauge, shown as H in Figure 3 was installed into the test system for tests conducted prior to those described here, and was not used for testing the fuzes.

c. With the vacuum pump running, valve B closed and valve C open, the test sample was inserted into the bomb and the steel lid put in place. Valve B was opened, and at the same time an electric stop watch was put in operation. After a predetermined time, ninety seconds in these tests, the internal pressure of the system was noted and valve C closed. With a tight system, any pressure increase must have come about from air inside the test sample, leaking into the test chamber. With a non-leaking fuze in the chamber, no pressure increase would occur. This was determined by conducting tests using a fuze in which all paths of possible leakage had been blocked off.

d. After the first series of leak tests, the samples were subjected to MIL-STD-304 and then retested as described above. The data obtained in making the leak tests are listed in Table 1.

e. Results of the tests of the fuzes manufactured by the Elgin Watch Company and the Bulova Watch Company are shown in Table 1. With the Bulova Watch Company samples, there were no leakers prior to MIL-STD-304. After cycling, five of the eight Bulova samples leaked at rates ranging from 0.6 to 26 x 10^{-4} cubic centimeters per second.

f. Following the leak tests and MIL-STD-304 it was discovered that the Elgin Watch Company samples were actually, as previously mentioned, unsealed fuzes. Through

some error, the thread sealing compound had not been applied to the booster holder prior to assembly. The error was discovered while breaking down the fuzes for inspection.

g. Following the sample breakdown, nine different points of the fuze mechanisms were inspected under the microscope for damage. This inspection was performed on all the subject fuzes. The degree of damage was assigned a numerical rating running from 1 to 5. An assignment of number 1 indicated that the part was completely free from any rust or corrosion. A number of 5 signified that the part was highly rusted or corroded. The numbers 2, 3, and 4 were assigned to the parts with some corrosion evident, depending on the degree of rust or corrosion present.

h. It was also noted by visual inspection that there was a green deposit on the bottom of the RDX lead cup on thirteen of the test samples.

i. Table 2 shows the fuze parts inspected, the qualitative rating of rust and corrosion, and the sums and averages of the numbers. The Bulova samples are not shown in the table because all parts on all Bulova fuzes inspected showed no damage from rust and corrosion and received a rating of 1.

j. The corrosion product, found on a number of the Elgin Watch Company fuzes, was inspected under the microscope. It had a chocolate brown color and did not appear to be a crystalline substance. However, using a 30X microscope, some of the material was brought into contact with concentrated hydrochloric acid. A formation of gas bubbles and brown colored solution indicated that the corrosion material was an oxide of iron.

k. The following opinions were formed from these tests:

(1) A visual examination after all fuzes had been subjected to MIL-STD-304, and then disassembled, showed no difference between fuzes made by Elgin Watch Company and those made by Bulova Watch Company.

(2) A microscopic examination of the same disassembled fuzes as in (1) showed that unsealed fuzes are more likely to be damaged by temperature and humidity than sealed fuzes.

(3) The size of leak did not correlate with damage ratings in some cases.

(4) The aluminum disc holder was the part most susceptible to corrosion, but it is not important to the operation of the fuze.

(5) The detent locking spring and the gear train in the acceleration arming mechanism appear to be more vulnerable to damage from rust and corrosion than any other parts that are vital to the operation of the fuze.

(6) The sealing method used in the Bulova test samples depreciated in effectiveness when subjected to temperature and humidity cycling. However, the short time accelerated test, MIL-STD-304, did not cause internal damage to the fuzes.

(7) Comparatively small leaks in a fuze might bring about internal damage over a long storage period, whereas the same leaks did not show enough corrosion to be discernible from a visual examination after exposure to MIL-STD-304.

11. Compatibility Studies

a. The compatibility of the explosive train components with associated metals was investigated and included 5 gilding metal lead cups from MIL-STD-304 which had the previously mentioned green deposit. The green deposit was found to be crystalline when examined under a 30X microscope and compared with some green crystals made by heating a strip of copper in stearic acid. This deposit is probably copper stearate, since stearic acid, which melts at 157° F, is used in the RDX booster and the 160° portion of the temperature and humidity cycle would cause it to flow and then attack the lead cup. The flowpoint of the stearic acid is within 3° (F) of the upper temperature requirement generally held for fuzes. Furthermore, it is not felt that the increase in sensitivity to that of pure RDX is great enough to constitute a safety liability. It is therefore felt that the intent of the required temperature range (-65° to 160°F) has been met.

b. To illustrate the effect of compromise of the lacquer seal on the primer and detonator, punctured and unpunctured samples of each mounted in open fuze bodies were

placed in a humidistat at 160° F and 95% relative humidity. The conditions and exposure times are listed in Table 3. One punctured unmounted sample of each was also included.

c. No rupture of the unpunctured primers or detonators occurred. White crystals grew out of all the punctured detonators. The disappearance of azide in these detonators was indicated by the lack of gas evolution where ceric ammonium nitrate solution was applied to these detonators. Two of the punctured primers showed no visible effects from exposure while one had a fine white powder sprinkled over the top. The white crystalline growth on the detonators is presumably $KClO_3$. Conditions in the primer apparently prevent this growth there. The two primers mounted over unpunctured detonators showed relatively clean surfaces adjacent to the detonators, as shown in Figure 5a. However, the two primers mounted over punctured detonators exhibited greenish crystals on the adjacent gilding metal surface, as shown in Figure 5b. Green and white crystals were also present on the top of the detonator, and white crystals in the fuze body. Ceric ammonium nitrate tests for azide on the bottom of the primer were positive. The possibility of formation of highly sensitive copper azides in the event of inadvertant puncture or poor seal of the detonator makes the use of gilding metal for the primer and rotor lead cups undesirable. The use of gilding metal as the cup for the primer is undesirable also since the primer contains lead azide. (Picatinny Arsenal Technical Report 1783 page 1554). The use of stearic acid in the RDX of the booster is also undesirable since the loss of stearic acid through fusion and flow at temperatures above 157° F could leave the RDX in a state of higher sensitivity, or impair explosive train performance. Conditions of natural environment that would raise the temperature of the fuze to 157°F or above do not occur very often, and when they do occur, steps can be taken to protect the fuze. The physical location of the primer and detonator make it appear that sensitive azide formation would be concentrated between them and in an area where detonator safety would not be impaired.

12. Package Evaluation

a. A complete pack was supplied according to the design shown in LD 291741. The pack consisted of an ammunition component box Mk 2 in which were placed seven metal trays. The trays were perforated in such a way as to provide support for the fuze at two places. Space is provided

for 75 fuzes. The total weight of the pack is 97 pounds, and was designated as Fuze Container Mk 119 Mod 0. This pack was given a complete laboratory evaluation. From the results obtained it was concluded that, taking into consideration the ruggedness of the fuze itself, the container design was entirely adequate to protect the fuze from damage due to transportation rough handling. However, when fully loaded the lid of the container could distort when subjected to drops. This means that the seal becomes ineffective following a drop and it is possible for water or water vapor to enter. To offset any extreme possibilities of such situations occurring, a hermetically sealed can to contain the fuze as an inner container was tested. This was a standard open top (packers type) can into which two paperboard supports are inserted to rigidly hold the fuze. These cans, with inert fuzes sealed inside, were also given a complete laboratory package evaluation while contained in the ammunition component box Mk 2. This package contained 72 canned fuzes per box. Prior to and after the package evaluation each, fuze loaded, sealed can was leak tested. Test results revealed the seal on the can to be satisfactory both before and after rough handling. The can was designated as the Mk 125 Mod 0.

b. As a result of these tests it was judged that two package designs would be approved for the fuze. One design will be the Mk 119 Mod 0 with trays to be used for interplant shipment within the continental United States and the second will be the hermetically sealed can (Mk 125 Mod 0) packed in the Mk 2 ammunition component box. The sealed can will provide protection for the fuze where long-term storage is expected.

ATTEMPTS TO IMPROVE PRODUCTION TESTING TECHNIQUE

13. Drop Tests

a. In an effort to improve upon and replace the testing technique (specified in the Static Action Test of the Requirements and Test Procedures (BUORD Drawing 1183386)), which had resulted in unreliable initiations of the fuze firing train, a drop test method was investigated. It was felt that a drop test would simulate, to a greater degree, service firing conditions. Design considerations for a drop tester were (1) simplicity of design, (2) economy of manufacture, and (3) adaptability to production testing.

The drop tester designed (Figure 6) consisted of a six-inch diameter pipe approximately 10 feet long. Supports consisted of 3 pieces of angle iron. A suitable fixture (Figure 7) was also designed to contain the fuze and the 1/8 inch mild steel information plate. The fuze was held in a piece of 1-1/2 inch American Standard welded steel pipe which was replaced with each shot. The pipe was cut to length such that the required distance of 3.00 ± .06 inches was maintained between the rear face of the holder (BUORD Drawing 1384950) and the steel information plate. The drop weight consisted of a 5-1/2 inch diameter cold-rolled steel slug weighing approximately 50 pounds.

b. The fuzes were prearmed and drop tests were conducted in a Probit type statistical test. Separate tests were conducted on production lot samples from both Elgin National Watch Company and Bulova Watch Company. Due to the limited height of the drop tester, energy levels beyond that obtained from a 10 foot drop were not investigated. The data of these tests proved to be quite inconclusive. Two unusual types of explosive train actions occurred which made it impossible to analyze the data. They were: (1) where the impact of the weight initiated the primer but the primer failed to initiate the detonator and (2) where all explosives were initiated but low order detonation of the booster occurred. Both of these occurrences were observed in fuzes from both manufacturers. They also occurred at different energy levels with the net result that no correlation of the data could be made. (Results of these tests appear in Table 4.)

c. Figure 8 shows an example of a primer failing to initiate the detonator. The detonator was driven past its retaining shoulder and out into the cavity for the arming mechanism by the explosion of the primer but was not initiated. Note that the bottom closing disc of the detonator was forced out and is lying on the rotor lead-in. Seven failures of this nature were observed in these tests. Since failure of the primer to initiate the detonator had been experienced in fuze acceptance tests, an investigation of this condition was conducted in an effort to determine its cause. It was suspected that the unreliable transfer from primer to detonator may have been attributed to the fact that as the primer is initiated, the bottom portion of the primer cup was coined out forming a disc which covered the sensitive end of the detonator thus interrupting the explosive train action. As a consequence of this

theory four of these units which had exhibited unreliable transfer were soaked in acetone until the tetryl and primary explosives of the detonator were dissolved. Figure 9 shows the results of this investigation. In each of the four cases, a small disc approximately the same diameter as the detonator was found lodged over the sensitive end of the detonator. Particular attention is directed to the cup in which the bottom portion is flanged outward but not completely sheared out. The results of this investigation appear to offer some evidence as to the reasons for the failures of the explosive transfer from the Primer M56 to the Detonator M29.

d. The other type of unusual explosive train action observed was where all explosives were initiated but low order detonation of the booster resulted. Figure 10 shows examples of NOTS 502A Mechanisms fired in this test. The damage to the Mechanism on the extreme right resulted from high order detonation of the RDX rotor lead-in and booster charge. Note the deformation at the base of the rotor housing. The two mechanisms in the middle are examples in which low order detonation of the rotor lead-in and booster charge occurred. The one mechanism on the left is an inert, unfired sample shown for comparison purposes. Although the damage appears quite severe at the top portion of the rotor in the two low order samples, the diameter of the lead-in hole (not shown) at the other end was relatively unchanged. Apparently the detonation wave "failed" although the RDX lead-in charge and booster charge underwent rapid decomposition (partially detonated) or burned in the process. Careful comparison of the detonator cavities of low order fuzes and high order fuzes showed that the cavity of the high order sample was considerably enlarged. To insure that this enlargement was not due to nor aided by detonation of the rotor lead-in charge, one fuze was fired containing only the Primer M56 and the Detonator M29. Sectionalization of this test sample revealed an enlarged cavity comparable to the high order sample. Seemingly then, the fault appears to lie in the detonator and its inability to provide sufficient output to properly propagate the detonation wave. If we assume that these were not faulty detonators, and this assumption seems plausible since low orders were observed in samples from both manufacturers who procure detonators from three independent sources, (Bulova from Hunter, and Elgin from Burmite and Olin) then this condition becomes difficult to explain. There is some reason to suspect that

the detonator did not receive an initial heat impulse sufficient to propagate a high order detonation to the tetryl base charge of the detonator. It is felt that the coining effect of the base of the primer cup could, in some instances, act as a baffle or insulator and allow only a minor portion of the energy impulse to be transmitted to the detonator, thus resulting in low order initiation. Another theory is that on initial impact by the primer, the detonator could be extruded past its shoulder and into the mechanism cavity as witnessed in Figure 8. However in this instance, at some very short period later the heat and pressure build-up would probably initiate the detonator. With the detonator in this position, with less confinement, the radial losses would be considerably greater thus resulting in a lower stable detonation velocity and an occasional low order detonation of the lead-in. Although it is not definitely known that the low order detonations were a result of either of the above-mentioned theories, it appears feasible that unreliable transfer would result under the circumstances of these tests. On the basis of these results it was felt that the test techniques and procedures did not provide a satisfactory method of statically firing the fuze. Furthermore as a result of these unreliable static explosive train tests and similar results from NOTS it would have been expected that field firing tests would have shown marginal firing train reliability. This, however, was not true. The field tests conducted on the fuze indicated very good firing train reliability. And so this difference in laboratory results and field results naturally led to the conjecture that the laboratory test, being a static simulation did not take into account the effects of velocity at impact.

14. Air Gun Test

a. An investigation was then undertaken to determine whether impact velocity was important to the firing train reliability or whether the observed malfunctions had been caused by some other factor. Therefore, the feasibility of using a modified air gun as a means of simulating actual impact conditions was investigated.

b. To very briefly describe the test, a target, constructed of any suitable material, impinges on the fuze at very high velocity. In other words, the relative velocity between fuze and target is obtained by propelling

the target while the fuze remains stationary. This target may, of course, have varying dimensions or material to satisfy most requirements.

c. In the belief that the solution to the problem at hand was best approached by operating at very high velocities, the simulator was set up for that condition, i.e. a two stage air gun to achieve velocities up to 1800 ft/sec. Later as data became available and the need for lower velocity impact data became evident, the use of the two stage air gun system was discontinued and the system was converted to a single stage impact simulator.

d. During the period in which the fuze impact simulator was used as a two-stage air gun, five "shots" were made using live-loaded fuzes. The target was constructed of aluminum and had a total weight of 5 ounces. The metal target thickness was nominally 1/4 inch throughout. Unfortunately, during this period, the instrumentation for determining the impact velocity was not completely reliable so that the precise velocities were in some doubt. Nevertheless sufficient data was obtained to show that target velocities in excess of 1800 ft/sec were obtained. In all tests where high velocity impact was achieved, the fuze fired high order. The left hand fuze of Figure 11 is a cutaway view of a fuze, which fired high order after impact at about 1800 ft/sec with a 5 ounce aluminum target.

e. In attempting to locate the velocity below which the fuze performance becomes marginal, the single stage simulator system was used and the target was changed to steel. This latter change was necessary when operating at relatively low velocities because the aluminum targets seized in the gun barrel and caused erratic behavior. The right hand fuze of Figure 1 is a typical low order fuze resulting from a low velocity impact. Table 5 shows the number of test shots that were made, the conditions under which the test was made and the results.

f. The results show that velocity of impact is indeed important to the efficient firing of the fuze. For the particular conditions under which these tests were performed the critical velocity appears to be in the range of 100 to about 200 fps (the highest velocity at which low-order detonation occurred was 150 fps). Therefore, at velocities above 200 fps the fuze will normally fire high order and below this figure there is a possibility of low

order detonation - or no detonation. It is important to note, however, that this figure applies only to impacts with steel targets of about 1/4 inch thickness.

g. The data indicate that variables other than velocity are also important to the efficient firing of the fuze. For example, it is noted that a magnesium target of comparable dimensions failed to detonate the fuze even though the impact was as high as 518 fps. It must be noted, however, that in this case all of the kinetic energy available (about 784 ft-lbs.) was not dissipated at the nose of the fuze because the target was penetrated by the fuze. This did not happen when steel targets were used. This means that the type of target material as well as the material thickness against which the fuze impacts, are important parameters. To combine all factors into one variable it may be assumed (so long as the impact velocity is greater than some presently unknown value) that the energy transfer at the nose of the fuze is the determining value. Sufficient data to determine the critical figures (or even to be assured that the theory is correct) are not available. Nevertheless, from the results it may be concluded that the energy transfer must (for this fuze) exceed about 450 ft-lbs, occur in less than 1/2 millisecond, and be dissipated at the nose of the fuze. Naturally, many high order detonations would occur at lower energy dissipation rates but it is doubtful if a significant number of low order detonations would occur where impacts meet or exceed the above conditions.

h. The above figures suggest that if certain conditions are not exceeded, the fuze performance may be expected to be erratic, but if the energy transfer is in excess of 450 ft-lbs and the time interval is very rapid, consistently efficient fire-through could be expected. Any malfunctions which occurred under such conditions are quite likely the result of a manufacturing defect of the fuze. Thus a performance test could be developed which would be a satisfactory check on assembly and manufacturing methods. Unfortunately the data given here are not sufficient to provide a really high confidence level.

15. Special Field Test. It was suspected that a fuze, sans the M56 Primer, could upon impact with a target fire high order because of the M29 detonator which contains a primer mix. To prove this out, ten rounds were fired during the period of air gun investigation, against 1/4 inch

mild steel plate at the Federal Ordnance Corporation, Mechanicsville, Maryland. In seven rounds the primer was replaced by soft wood and in three rounds the primer cavity was empty. All ten rounds functioned high order. All the rounds were fired at 0° obliquity so it is not known what the effect would be at higher obliquities. This test indicated that the reliability of the round may be partly dependent on the ability of the detonator to fire the fuze train.

ARMING DISTANCE TESTS

16. Determination of Arming Distance. Arming distances were obtained for a group of 90 fuzes Mk 181 Mod 1 fired from a zero length launcher with Motors Mk 1 Mod 3 and Heads Mk 1. In order to avoid the delay of ordering the Heads Mk 5 (which is the head used with this fuze) from the Air Force, it was decided to use Heads Mk 1 loaded to the weight of the Head Mk 5. After the tests with Motors Mk 1 Mod 3 were about half completed, it was decided that the new Motors Mk 3 Mod 1, being relatively insensitive to temperature change over the temperature range of interest, should be used. This was done during the remainder of the test.

17. Centrifuge Tests. All fuzes were first timed in the laboratory on a centrifuge similar to the one used by the manufacturer. Arming times obtained, together with the arming times furnished by the manufacturer, are listed in Table 6. During these tests it was noted that: (1) when tested more than once at the same acceleration, the arming time varied by as much as 0.05 second; (2) there was a particularly large variation between the first run and subsequent runs; (3) the rotor can turn through about 10% of its full rotation before the set-back weight is released and the electric timer which measures the arming time is started, and; (4) in the centrifuge the actual acceleration for various parts of the fuze mechanism varies from about 38g to 42g, depending on the distance to the center of rotation of the centrifuge. In particular, since the speed of the centrifuge is set to provide 40g at the trunnions, the pendulum itself is oscillating in an acceleration field of more than 40g. In actual use with a Rocket Motor Mk 3 Mod 1, the acceleration is linear and changes from about 41.5g at firing to about 73.6g at motor burnout (at 70°F). Thus, these facts indicate that the arming distance of any individual fuze cannot be determined accurately from its arming time on a centrifuge.

18. Fuze Modifications. As shown in Figure 12, an insulated wire was inserted through the base of the fuze mechanism so that the rotor would contact it just before it reached the fully armed position. At this time the rotor has become disengaged from the gear train and is in free swing towards the locked position. The rotor is approximately 5° from the locked position, but due to the rapidity with which it is moving at this time the difference in both time and elapsed rocket travel between the 5° point and the fully armed position is negligibly small. The NOTS report states that the fuze firing train is 50% reliable about 10° before the locked position. In those few rounds which did not puff it cannot be stated that the fuzes were defective. Although the modifications do not affect the operations of the mechanisms in any way, it must be realized that whenever a fuze mechanism is removed from the fuze body for modification there is a possibility that foreign metal particles may be overlooked, even though all precautionary measures may be taken. Too, the possibility of primer and/or smoke puff failure must be considered.

19. Indicating System. The wire contact which was added to the fuze mechanism was connected through a Primer Mk 113 in series with an 0.1 mfd, low leakage condenser, to ground. The "hot" lead of the condenser was led out through a small hole drilled in the side of the fuze body. A smoke puff consisting of 110 grams of black powder and aluminum powder mixture in a steel tube, was placed in the rocket head so that when the fuze was screwed into the head, the end of the primer was close to the end of the smokepuff. In these tests the Naval Proving Grounds, Dahlgren, Virginia, where these field firing tests were conducted, departed from their usual technique in that no holes were drilled in the head to facilitate release of the smoke and flash. The method was satisfactory as far as visibility was concerned, but when the flash occurred the rocket deviated sharply. This had no effect on the results since the desired data were obtained before the deviation occurred.

20 Launching and Recording Gear.

a. The launcher used for these tests was improvised from a section of steel pipe with the correct internal diameter, welded to a Mk 31 Rocket Launcher set at 10° Q.E. The nose of the rocket was allowed to protrude from the front end of the pipe far enough to permit attaching a lead to the charging electrode on the side of the fuze.

The other charging lead was grounded to the launcher. The leads were run a short distance to the Reprisal Shelter (a testing station at NPG), which contained the charging gear and the NPG Sequence Timer. The charging gear was designed so that the fuze could be shorted out while it was being adjusted in the launcher, and the charge on the condenser could be monitored up to the time the rocket was fired to ensure that the voltage loss caused by leakage was not excessive. Leakage during the tests was negligible except for the tests at 160° F, and even though it was more noticeable at that temperature it was not severe enough to cause any trouble. The 250 volts used to charge the condenser was well above the minimum voltage required to initiate the Primer Mk 113.

b. The recording cameras were located at Topside, a place which commanded a broadside view of the launching range. The field of view included the 50-foot checkerboard markers for distance, and an electric timing clock to indicate elapsed time. The cameras were started by the sequence timer at Reprisal a short time before the rocket was fired, and zero time was marked by the timer at the instant of firing. This is the standard equipment used at NPG for all rocket launcher tests, so it will not be described in greater detail here. A sample frame enlargement showing the flash of the smokepuff at arming is included as Figure 13.(Note rocket firing in upper right hand section of the figure.)

21. Rotary Accelerator Test. At the end of the first phase of the tests with Motors Mk 1 Mod 3, it was not known for certain that the wide dispersion in arming distances was due to the temperature-sensitivity of the motor. (Theoretically the arming distance of the fuze is independent of the value of the acceleration.) A theory evolved that the poor results were caused by sideways accelerations in the rocket, and in order to test this theory, tests were run using the rotary accelerator. The fuzes were lined up at an angle of 20° from the direction of acceleration, and were timed in four positions (set-back weight at 0°, 90°, 180°, and 270°). The average arming times recorded varied from 0.755 second at 180° to 1.005 seconds at 0°, in such a fashion as to suggest that a sideways acceleration in one direction would increase the arming time about as much as sideways acceleration in the opposite direction would decrease it. Similar tests with a Fuze Mk 181 Mod 0 brought out the fact that in two positions with sideways

acceleration the fuze would not arm at all. Even though these tests used an exaggerated amount of constant sideways acceleration, instead of the sideways vibration which would probably be encountered in actual rocket flight, there is a possibility that the dispersion in the arming distances may in part be caused by this effect. Data will be discussed later.

ARMING DISTANCE STUDY

22. Introduction

a. The purposes of this study are to (1) develop and discuss a method of predicting the arming distances of the subject fuze (and similar fuzes) from the arming times obtained on a centrifuge, and (2) to predict the arming distances for that lot of the subject fuze from which the samples were obtained. The basic data utilized were from field tests which were performed on fuzes which had been timed in the laboratory (paragraph 17.) and modified as described in paragraph 18.

b. The method of predicting arming distances in the field based on laboratory (centrifuge) times which will now be presented, is essentially as follows:

(1) A constant acceleration time-distance relationship is assumed (field time) and a curve showing this assumed relationship is fitted to the data. Since there are additional sources of variation inherent in field firing (such as that caused by variation between rocket motors) and the assumed constant acceleration is an approximation, there will be a spread of data points about the fitted curve.

(2) Given the above relationship of field arming times and distances, it is used to determine from the observed distances their "equivalent field arming times". The problem of predicting arming distances then reduces to that of predicting these equivalent field arming times from laboratory arming times.

(3) It was assumed that the arming times (both the laboratory and equivalent field) were normally distributed.

(4) The mean equivalent field arming time for each temperature was expressed in terms of the mean laboratory arming time.

(5) For each temperature studied the standard deviation of the equivalent field arming times was expressed in terms of the standard deviation of the laboratory arming times.

c. The arming distance distribution could then be discussed in terms of the equivalent arming distance distribution by using the constant acceleration time-distance curve discussed in 22.b.(1). This method of prediction could be tested by comparing the results predicted (by it) for a given set of fuzes with the results observed in the field with the same set of fuzes. If a sufficient amount of useable data were obtained from the original field tests, half of it (randomly determined) could be used as discussed in paragraph 22.b. and the remaining half could be used to test the validity of this prediction method.

23. Laboratory Arming Tests. Ninety (90) Fuzes Mk 181 Mod 1 were modified as mentioned in paragraph 18, so that a smokepuff would be produced at the time the fuze armed. All fuzes were timed on a centrifuge (at 40 g) similar to the one used by the manufacturer. Large amounts of these centrifuge times have been collected by the manufacturer and appear to be normally distributed. The ninety (90) laboratory arming times are listed in Table 6 and plotted in Figure 14. Certain pertinent facts noted in paragraph 17 about these laboratory time tests are here relisted:

a. Arming times of a particular mechanism changed by as much as 0.05 second in subsequent runs at the same acceleration, and

b. The fuze rotor can turn through about 10% of its full rotation before the setback weight is released and the electric timer which measured the laboratory arming time is started.

24. Field Arming Tests

a. These ninety (90) fuzes were fitted to rounds, conditioned at one of three temperatures, -60°F, 50°F, or +160°F, and fired from a zero length launcher. Arming distances and times were recorded photographically and corrected for the known delay in the indicating system.

b. These field arming tests were conducted in two phases. The first phase consisting of 39 rounds produced rather erratic results which were believed to have been caused by the temperature sensitive (and outdated) Motors Mk 1 Mod 3 with Propellant Grain Mk 31 then being used. In the second phase the remaining 51 rounds, Motors Mk 3 Mod 1 (with Propellant Grain Mk 43 which was believed to be less sensitive to temperature variation) were used. The remaining fuzes were randomly assigned (in equal numbers) to the three test temperatures. The results of both phases (observed field time and distance) are also shown in Table 6.

c. The variation in times were significantly smaller for the Motor Mk 3 for the two temperatures where this comparison could be made (-60°F and 50°F). Only the latter tests (with Motors Mk 3 Mod 1) will be discussed herein since these data are believed to be more representative of the present (and future) motors with which the Fuze Mk 181 Mod 1 might be used.

25. The Time-Distance Relationship

a. It has been assumed herein that, over the time range of interest, the time-distance relationship for this rocket could be sufficiently well approximated by assuming that the resultant acceleration of the round was constant or that

$$D = kt^2 \text{ (from } \frac{d^2D}{dt^2} = K = 2k \text{ and } D_o = \left(\frac{dD}{dt}\right)_o = 0).$$

Figure 15 shows the fitted curves of this form for the data from the three temperatures, as well as the curve assuming that the value of this constant acceleration is 40g. It is interesting to note that those fuzes, where something went wrong, resulting in extremely short or long arming and therefore of little value as arming distance data, were of great value in fitting these curves.

b. These curves appear to adequately describe the data over the time range of interest. The data are spread about the curves since (1) the constant acceleration assumed is an approximation, and (2) (of more importance) there is motor to motor variation.

26. Equivalent Arming Times

a Given the assumed time-distance relationship

discussed in the last paragraph, $D = kt^2$, it can be used to determine a "time" for each arming distance by $t' = \sqrt{D/k}$, where k has been determined for the several test temperatures. These "equivalent field arming times" now include all the dispersion of the arming distances in terms of time. It is assumed that these t' are distributed normally since; (1) the arming times of the fuzes under a constant acceleration (laboratory arming times τ) appear to be normally distributed; (2) the deviation from constant acceleration, which the fuze is subjected to, over its arming interval in the field does not appear to be appreciable in its effect on the shape of the distribution of times given by the fuzes; and (3) the effect discussed in (2) as well as the other dispersion introduced in firing in the field (such as that caused by differences between rocket motors and transverse accelerations on the fuze resulting from unstable flights) are small compared to, and independent of, the distribution of laboratory arming times. There are no significant differences between the variances of these equivalent field times for the several temperatures. Although the means were significantly different, the observed differences (in means) were very close to the amounts necessary to compensate for the differences between the ambient and the extreme temperature time-distance relationships discussed in paragraph 25.a. In other words, the fuze is successful at compensating for the mean temperature effect observed in the Motor Mk 3 Mod 1. Figure 14 also shows the distribution of these t' for all temperatures with extreme temperature data corrected to bring their mean times to the mean ambient time (to show the shape of the distribution of t' after removal of the temperature effect).

b. The problem of predicting the distribution of arming distances (D) from the distribution of laboratory arming times (τ) has now been reduced to that of predicting the distribution of equivalent field arming times (t') from laboratory arming times. One known source of added dispersion in time in the field and which will not occur in laboratory centrifuge tests is that due to the approximately 10% free rotor travel before release of the setback weight. At the time of firing in the field it is felt that this rotor is equally likely to lie anywhere within its free travel range. It has therefore been assumed that this extra time is distributed rectangularly between 0 and 0.10τ, giving a mean extra time of 0.05τ and an effective standard deviation of $\approx \tau/35$.

The 1st and 2nd moments of a rectangular distribution between a and b are $\mu_1 = 1/2\ (a + b)$, and

$$\mu_2 = \mu_2^1 - \mu_1^2 = 1/3 \left(\frac{b-a}{2}\right)^2$$

If $a = 0$ and $b = 0.10\bar{\tau}$ then

$$\text{mean} = \mu_1 = 1/2\ (0 + 0.10\bar{\tau}) = 0.05\bar{\tau}$$

$$\text{S.D.} = \sqrt{\mu_2} = \frac{b-a}{2\sqrt{3}} \cong \frac{0.10\bar{\tau}-0}{3.5} = \bar{\tau}/35.$$

It is also assumed that this time is independent of the individual laboratory time.

c. For each temperature the mean equivalent field arming time $\bar{\tau}'$ might be listed as the sum of the mean laboratory arming time and the mean extra time discussed above plus a correction. If this were done it would be seen that the resulting corrections would quite adequately compensate for the differences between the time-distance curves for the several temperatures shown in Figure 15. Thus, only one correction and one curve would do to relate mean times for all temperatures. Moreover, if the 40 g constant acceleration curve is used no correction is necessary. The mean equivalent field arming time $\bar{\tau}'$ is estimated as $\bar{\tau}' = 1.05\bar{\tau}$ and from this the 50% arming distance $D_{50\%}$ can be estimated by the constant 40g time distance relationship

$$D = 1/2\ (40g)\ t'^2$$

$$= 644\ t'^2.$$

Arming distance percentiles rather than mean and standard deviation will be discussed since (1) the arming distance distribution is not symmetric and (2) the percentiles are the desired information.

d. For each temperature the standard deviation of the equivalent field arming time might be listed as the square root of the sum of the variances of the laboratory times and the extra times plus a correction. If this were done it would appear that the corrections necessary to predict

standard deviations of the equivalent field arming times from those of the laboratory times were larger at the extreme temperatures. It seems plausable that more erratic rocket behavior might occur at the extreme temperatures which could not be entirely compensated for by the integrating capabilities of the fuze. However, there is not sufficient data to establish whether or not such a relationship holds (data at three temperatures only). In addition, no significant differences between the variances of the t' distributions at the several temperatures were revealed so the several estimates were pooled. It is known that the fuzes assigned to the different field test temperatures were randomly selected (though the variance of one group would test significantly smaller) so the several estimates were pooled to provide one estimate s_{τ}. Using these pooled estimates the correction which must be added to the sum of the laboratory time variance and the extra time variance to predict the variance of the equivalent field arming times was next estimated. With this correction (which is the third term under the radical below) the standard deviation of the equivalent field arming time distribution may be estimated as

$$s_{t'} = \sqrt{s_{\tau}^{\,2} + (\bar{\tau}/35)^2 + .0005}.$$

27. Field Arming Distance

a. With the estimates $\bar{t}'$ (paragraph 26.c) and $s_{t'}$ (paragraph 26.d) the various percentiles of this distribution (values of t' below which a given percent of the distribution lies) may be estimated by consulting a table of areas under a normal curve. Some of the t' percentiles are now given in terms of $\bar{t}'$ and $s_{t'}$:

$$t'_{1\%} = \bar{t}' - 2.33\, s_{t'}$$

$$t'_{5\%} = \bar{t}' - 1.645\, s_{t'}$$

$$t'_{50\%} = \bar{t}'$$

$$t'_{95\%} = \bar{t}' + 1.645\, s_{t'}$$

$$t'_{99\%} = \bar{t}' + 2.33\, s_{t'}$$

As implied above, any given percentile of the equivalent field arming time distribution can be used to estimate the corresponding percentile of the arming distance distribution by the constant 40g acceleration relationship $D_{p\%} = 644\ (t'_{p\%})^2$.

b. The field arming distance percentiles will now be estimated for the subject fuze. Of course, the results should appear quite adequate since the model is now being used to predict the data upon which it is based. The laboratory arming time distribution parameter estimates are $\bar{\tau} = 0.75$ sec. and $s_{\tau} = 0.03$ sec., so

(1) $\bar{t}' = 0.79$ sec. and $s_{t'} = 0.04$ sec.

(2) $t'_{1\%} = 0.70$ sec.

$t'_{5\%} = 0.72$ sec.

$t'_{50\%} = 0.79$ sec.

$t'_{95\%} = 0.86$ sec.

$t'_{99\%} = 0.88$ sec.

(3) $D_{1\%} = 316$ ft

$D_{5\%} = 334$ ft

$D_{50\%} = 402$ ft

$D_{95\%} = 476$ ft

$D_{99\%} = 499$ ft

This predicted distribution and a histogram of the observed arming distances are shown in Figure 16.

28. <u>Predictions for a Similar Fuze</u>

a. The T-2023E1 was a fuze similar to the Fuze Mk 181 Mod 1 except that it inherently provided somewhat longer arming times. The main difference between the Mk 181 Mod 1 and the T-2023E1 was that the T-2023E1 possessed an adjustable escapement mechanism. Predicting the arming distances of the T-2023E1 from its laboratory arming times as described above and comparing the results with arming distance

estimates based on field tests should provide some indication of the merit of such prediction methods. However, the data on the T-2023E1 (both laboratory arming times and field arming distances) are quite sketchy so this will provide only a rough comparison.

b. Nineteen T-2023E1's had been timed on a centrifuge (at 40g) 5 times each and the 19 mean times were available to provide an estimate of the distribution of arming times, and are given in reference (d). However, using the mean of 5 readings on each mechanism instead of single readings to estimate the distribution of arming times would result in under-estimating the variance of this distribution, since the variation of the times of individual mechanisms about their means is removed when a mean is used instead of a single reading. The individual times were therefore obtained from NOTS, and the first of the times obtained on each mechanism were used to estimate the distribution of times. For these first times $\bar{\tau} = 0.792$ sec. and $s_{\tau} = 0.032$ sec. as compared with $\bar{\tau} = 0.782$ sec. $s_{\tau} = 0.026$ sec. for the means of five. The five readings and the mean time obtained on each mechanism are presented in Table 7.

c. The laboratory arming time distribution estimates for the Fuze T-2023E1, $\bar{\tau} = 0.792$ sec. and $s_{\tau} = 0.032$ sec., are now used to predict the field arming distance estimates in the manner discussed in paragraph 27, and implemented for the subject fuze in paragraph 27.b.

(1) $\bar{t}' = 1.05\,\bar{\tau} = 0.83$ sec.

$s_{t'} = \sqrt{.0010 + .0005 + .0003} = \sqrt{.0018} = 0.04$ sec.

(2) $t'_{1\%} = 0.83 - 2.33\,(.04) = 0.83 - 0.10 = 0.73$ sec.

$t'_{5\%} = 0.83 - 1.645(.04) = 0.83 - 0.07 = 0.76$ sec.

$t'_{10\%} = 0.83 - 1.28(.04) = 0.83 - 0.05 = 0.78$ sec.

$t'_{50\%} = 0.83$ sec.

$t'_{95\%} = 0.83 + 0.07 = 0.90$ sec.

$t'_{99\%} = .83 + 0.10 = 0.93$ sec.

(3) $D_{1\%} = 343$ ft

$D_{5\%} = 372$ ft

$D_{10\%} = 392$ ft

$D_{50\%} = 445$ ft

$D_{95\%} = 522$ ft

$D_{99\%} = 558$ ft

d. Twelve T-2023E1 fuzes were fired at NOTS to obtain an estimate of the 10% arming distance and are reported in reference (d). NOTS gave 410 feet as the estimated 10% arming distance based on these data. The 10% arming distance estimated from laboratory arming times was listed in the last paragraph as 392 feet. This provides one of the two comparisons which will be made between estimates based on laboratory arming times (by the methods described herein) and those based on field tests. From the few rounds fired in the field a rough estimate of 470 feet was obtained for the 50% arming distance. Assuming (as before) that the square roots of the arming distances ("time") are normally distributed, then this estimate might more properly be given as $\bar{x} \cong 21.7$ (where $x = \sqrt{D}$). No useful estimate of s_x could be obtained from such sparce data. Field tests were also performed on the T-2023E1 at Picatinny Arsenal. The resulting data were obtained from reference (e) and resulted in the (rough) estimates $\bar{x} = 21.5$ and $s_x = 1.0$. The two estimates of $\bar{x}$ were combined by taking their mean (they were considered of equal worth) so that the estimates of the distribution of x based on field tests are $\bar{x} = 21.6$ and $s_x = 1.0$. Estimates of various percentiles of the distribution of x were next computed and are here listed:

$$x_{1\%} = 21.6 - (2.33)(1.0) = 21.6 - 2.3 = 19.3$$

$$x_{5\%} = 21.6 - (1.645)(1.0) = 21.6 - 1.6 = 20.0$$

$$x_{10\%} = 21.6 - (1.28)(1.0) = 21.6 - 1.3 = 20.3$$

$$x_{50\%} = 21.6$$

$$x_{95\%} = 21.6 + 1.6 = 23.2 \text{ and}$$

$$x_{99\%} = 21.6 + 2.3 = 23.9$$

The squares of these values are estimates of the arming distance percentiles based on field tests and subject to the assumption that $x = \sqrt{D}$ is normally distributed. These are now listed:

$D_{1\%} = 372$ ft

$D_{5\%} = 400$ ft

$D_{10\%} = 412$ ft

$D_{50\%} = 467$ ft

$D_{95\%} = 538$ ft and

$D_{99\%} = 571$ ft

First, it may be seen that the $D_{10\%}$ is fairly close to the estimate of this percentile resulting from the NOTS field test. This agreement tends to add some to the creditability of these arming distance percentiles.

e. A comparison of the T-2023E1 arming distance percentile estimates based on field test results (paragraph 28.d.) with those based on laboratory arming times by the method derived in this report shows that the field test percentiles were consistently greater than those predicted from laboratory arming times. The difference observed could be explained by a difference in mean laboratory arming times of 0.02 sec. Such a difference in mean times would be quite unlikely with random selection of test samples from the whole production but is quite possible between groups where random selection has not been assured. A more believable cause of the discrepancy is that the field estimates obtained (small usable sample size and go no go results) were in error. An error of 20 feet in an estimate of the 50% arming distance obtained such as was that used herein is quite believable. Another quite possible cause of the observed discrepancy is that the method of predicting field arming distances from laboratory arming times derived herein is not adequate. Since no truly applicable data seems to be available it would seem to be advantageous to randomly select a group of fuzes, Mk 181 Mod 1, T-2023E1 or some similar to these, time them in the laboratory and test them in the field (preferably modifying them to provide smokepuff at arming) and test the prediction method described herein against these data. Even if the prediction method is found wanting these additional data would prove useful in deriving a better one.

29. Summary

a. Given the $\bar{\hat{t}}$ and $s_{\hat{t}}$ of a sample from a lot of Mk 181 Mod 1 Fuzes (or a similar fuze) estimates of the percentiles of the distribution of arming distances of the lot may be obtained in the following manner:

(1) obtain equivalent field arming distance distribution parameters $\bar{t}' = 1.05\,\bar{\hat{t}}$ and $s_{t'} = \sqrt{s_{\hat{t}}^2 + (\bar{\hat{t}}/35)^2 + .0003}$.

(2) obtain the several percentiles of interest for this distribution

$$t'_{1\%} = \bar{t}' - 2.33\, s_{t'}$$

$$t'_{5\%} = \bar{t}' - 1.645\, s_{t'}$$

$$t'_{50\%} = \bar{t}'$$

$$t'_{95\%} = \bar{t}' + 1.645\, s_{t'}$$

$$t'_{99\%} = \bar{t}' + 2.33\, s_{t'}$$

(3) Transform these percentiles into the desired corresponding arming distance percentiles by the relationship

$$D_{p\%} = 644\,(t'_{p\%})^2.$$

b. Estimates of the laboratory arming time distribution parameters were available from a group of T-2023E1 fuzes. The field arming distance distribution percentile estimates predicted from these laboratory arming times by the method derived herein were in fair agreement with arming distance percentiles estimated from other groups of T-2023E1 fuzes tested in the field, considering the possible error in the estimates based on field test data.

30. Critique and Limitations

a. Equally valid methods of predicting the arming distance percentiles of this particular lot of fuzes could have been derived in a much more direct manner. However, it is of more general interest to be able to estimate arming distances of other lots and other similar fuzes.

b. Although the arming distances predicted from laboratory arming times of the T-2023E1 appear to be in fair agreement with the estimates based on field tests, the method of prediction is still actually untried because of the limited (applicable) field data on the T-2023E1. If all 90 Fuzes Mk 181 Mod 1 had been tested with the Motor Mk 3 Mod 1, sufficient data would have been available both to derive the prediction method (or model) as was done above, and also to test it. This would have been done by randomly selecting the half of the data against which the predicted results would have later been tested. As it is the model still wants testing.

c. It should be mentioned that although the fuze has demonstrated integrating capabilities, it seems that these capabilities are overstrained when used with the highly temperature sensitive Motor Mk 1 Mod 3. It is therefore necessary to limit any methods presented concerning predicting the arming distances of this and similar fuzes to apply only when used in conjunction with the Motor Mk 3 Mod 1 or motors similar to the Mk 3 Mod 1 in (1) temperature sensitivity, (2) acceleration pattern and magnitude over the arming interval, and (3) motor to motor variation.

d. Discussion in paragraph 21.a. implied that transverse accelerations might radically affect the arming times given by the fuze. Since the method of launching affects stability, at least early in the flight of the rocket, it seems prudent to also add the limitation that the above discussed prediction methods should be expected to apply only when similar rocket launching methods are used. This consideration would tend to indicate that the only really meaningful launching vehicle (method) would be either a flying platform or a simulated one.

CONCLUSIONS AND RECOMMENDATIONS

31. The evaluation results on the Mk 181-0 (T-2023E1) were reported to the Bureau of Ordnance by reference (a). The Mk 181-0 and Mk 181-1 were recommended for release to production by reference (b).

32. The fuze evaluation revealed certain areas of marginal design, which were discussed in this report and in the final NOTS report (reference (d)). They are listed briefly below.

a. Marginal reliability between primer and detonator as indicated by static firing train tests.

b. Weaknesses of static action acceptance tests with regard to checking fuze explosive train performance.

c. Unreliability of fuze sealing which may result in poor operability after long term storage.

d. Lack of safety devices to prevent assembly of the fuze mechanism in the armed position.

e. Powdering of RDX in the explosive train as a result of jolt and jumble tests.

33. Effort was expended toward reducing some of the possible mal-effects which may result from the above marginal features. This effort resulted in (1) an X-ray or visual inspection test being added to the RTP, to reduce the chance of assembly of armed fuzes, (2) because of the difficulty of obtaining reliably sealed fuzes in the present design, the Laboratory recommended and provided an alternate packaging design for the fuze. This package is to be used where long term storage is contemplated. The package consists of an hermetically sealed can packaged in a Mk 1 of Mk 2 Ammunition Component Box. This step was also the recommendation of the Naval Ordnance Test Station after the evaluation of the T-2023E1 fuze. It is recognized that this is not a substitute for fuze sealing, but will offer some protection to the fuze mechanism prior to its assembly in the heads, and (3) the Laboratory conducted an investigation of methods to improve the Static Action Test of the RTP. It was determined that a simple drop, which would be feasible for a testing activity, would not reliably initiate the fuze. The air gun system which was developed allows reliable initiation but is probably impracticable from a cost and operation standpoint for a testing activity.

34. On the basis of the evaluation tests conducted on the (T-2023E1) Mk 181-0 and Mk 181-1, the fuzes are considered to be adequately safe, reliable, and effective as a fuze for an antitank rocket. It is pointed out that the fuze is not a sealed fuze and, as such, tests have indicated that its shelf-life may be questionable when stored in other than a sealed container; because of this, it was recommended that, to the extent practical, the fuze be

stored and transported in the fuze can rather than in the unprotected round.

35. The arming distance tests which comprised much of the effort of this program at NOL indicated that the arming distance distribution of the Mk 181-1 using the Mk 3 Mod 1 Motors with Propellant Grain Mk 43 are as follows: 5% of the fuzes arm at 334 feet, 50% at 402 feet, and 95% at 476 feet. These values are for fuzes fired at ambient temperatures (50°F - 80° F).

36. If extensive use of this fuze is contemplated, consideration should be given to developing a new Mod which would (1) incorporate a sealed mechanism, (2) incorporate an anti-malassembly feature, (3) improve the reliability of the primer detonator combination, and (4) eliminate the lead azide-gilding metal combination in the primer.

CONFIDENTIAL

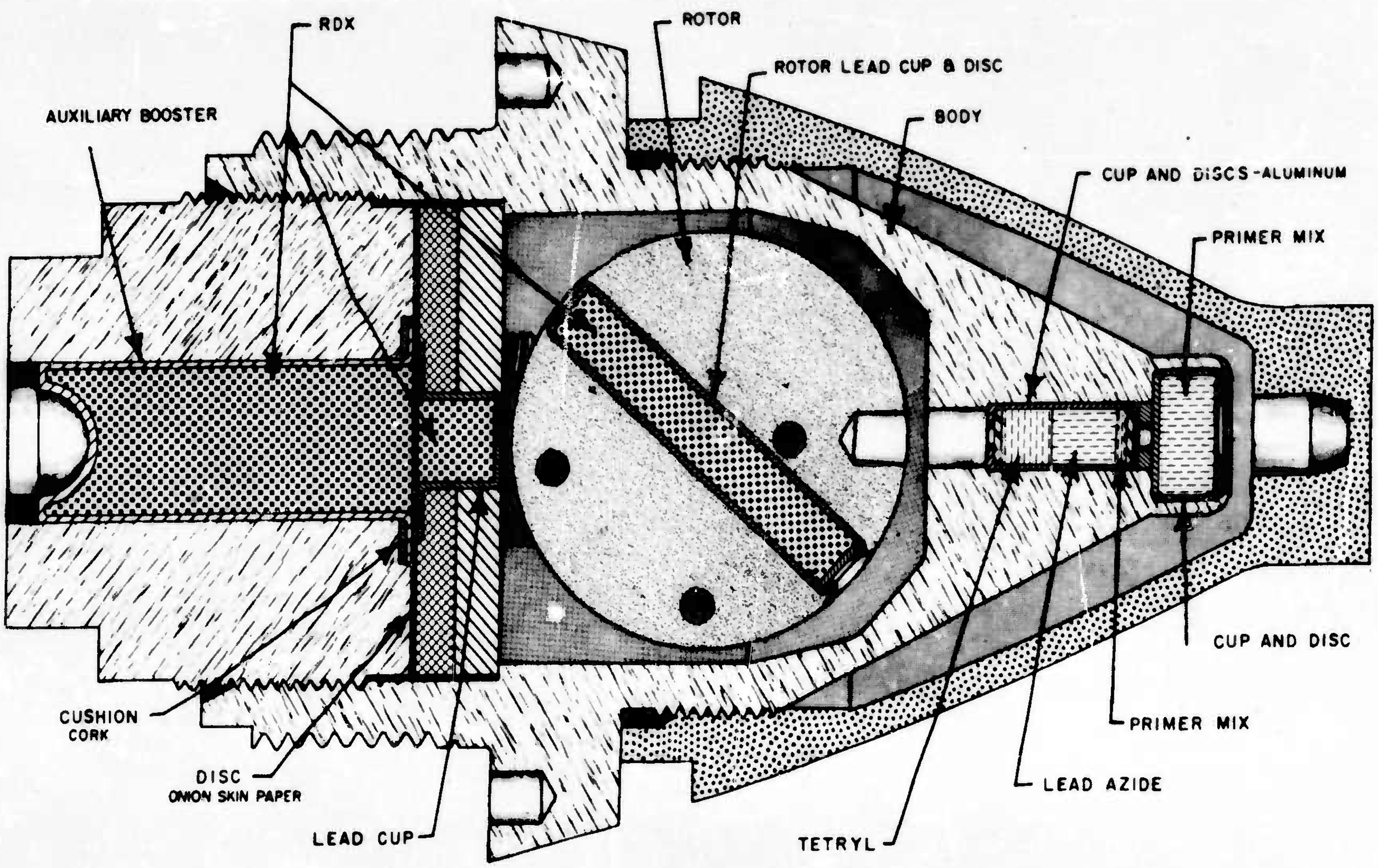


FIG. 1 FUZE MK 181 MOD 0

CONFIDENTIAL

- NAVORD REPORT 5751 -

TOP VIEW

SIDE VIEW

FIG.2 MAGNIFIED VIEWS OF RUST FORMATION ON THE DETENT

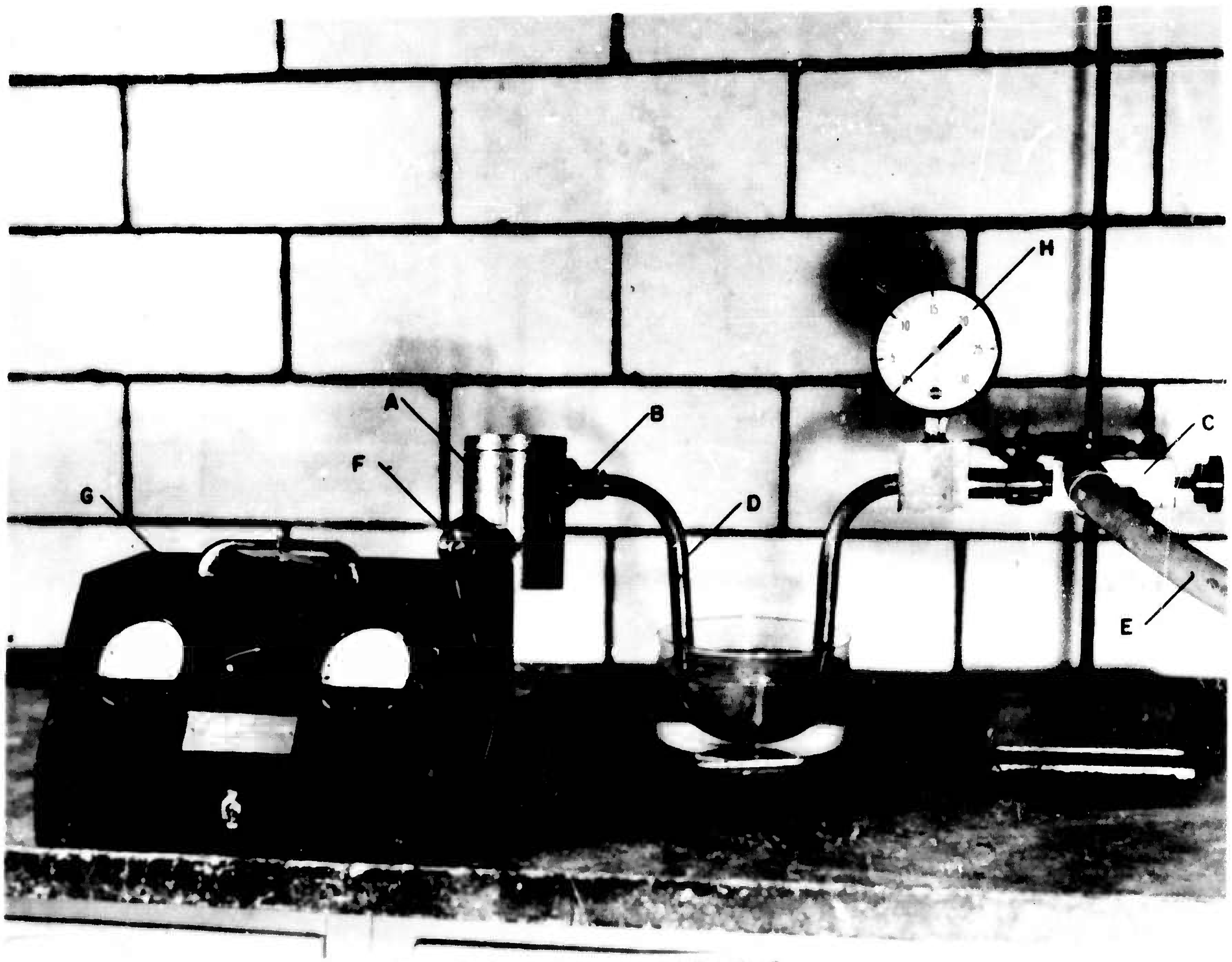


FIG 3 LEAK RATE APPARATUS

CONFIDENTIAL

FIG. 4 DETAILS OF BOMB USED IN LEAK TESTING

FIG. 5a PRIMER MOUNTED OVER UNPUNCTURED DETONATOR
PICTURED AFTER 72 HOURS AT 160 DEGREES FAHRENHEIT & 95 %R.H.

FIG 5b PRIMER MOUNTED OVER PUNCTURED DETONATOR
PICTURED AFTER 22 HOURS AT 160 DEGREES FAHRENHEIT & 95% R.H.

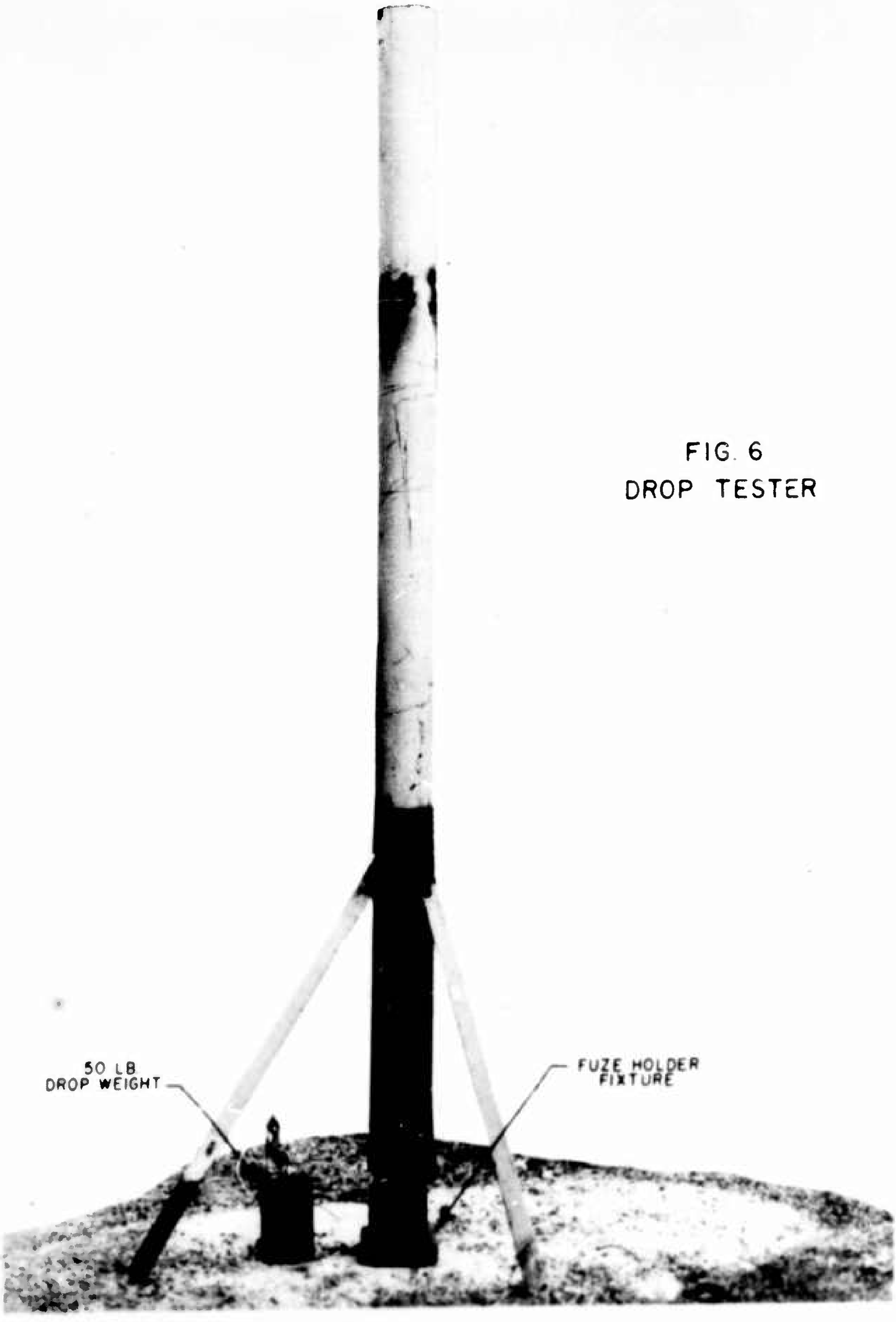


FIG. 6
DROP TESTER

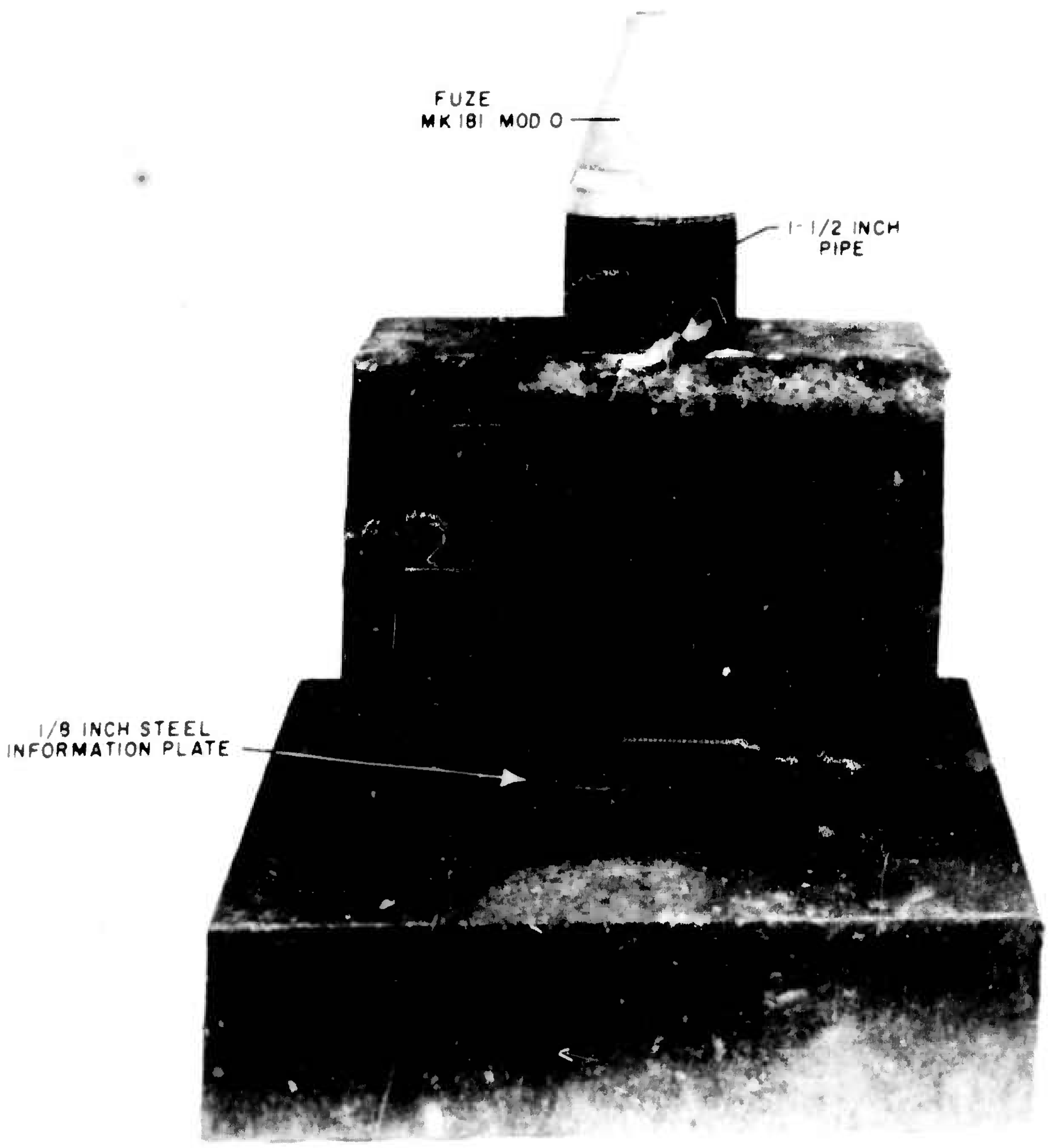


FIG 7 FUZE HOLDER FIXTURE

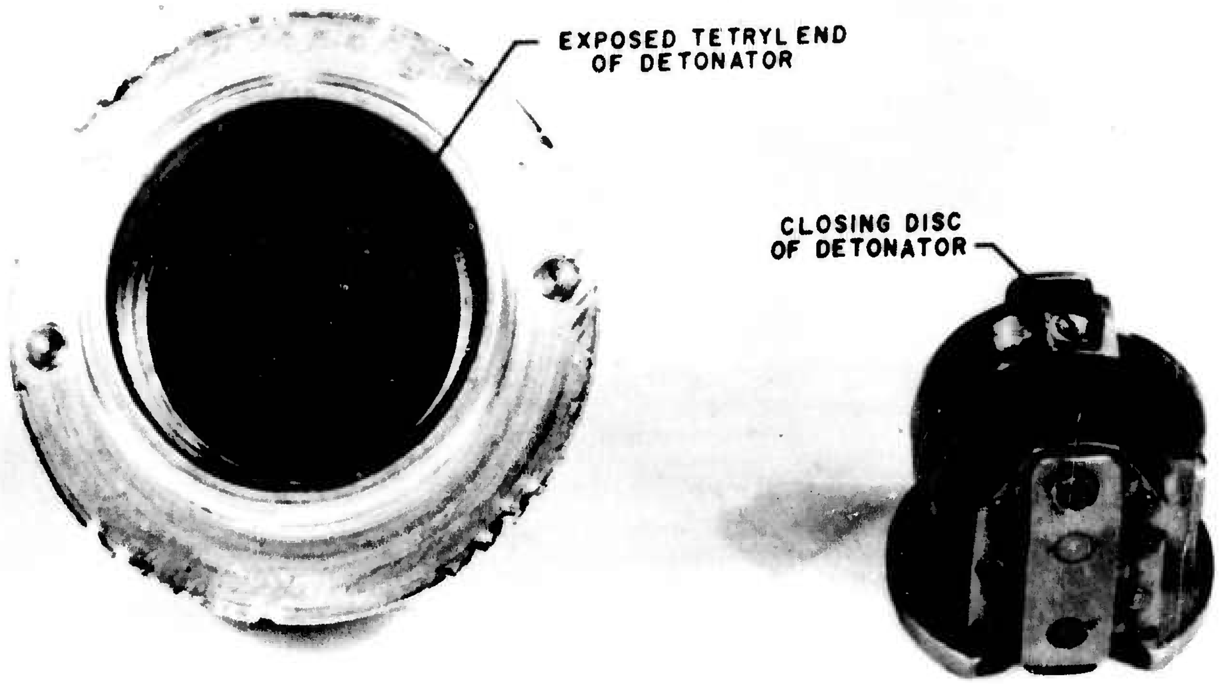


FIG. 8 EXAMPLE OF PRIMER M- 56 FAILURE TO INITIATE THE DETONATOR M- 29
(FUZE MK 181 MOD 0)

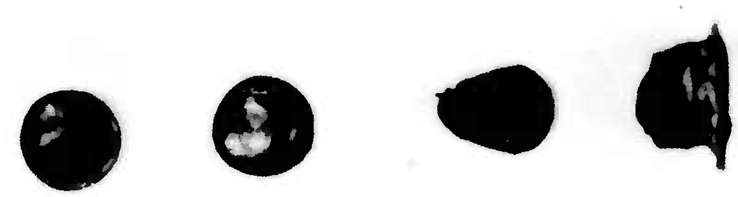


FIG. 9 GILDING METAL DISCS COINED OUT FROM BASE OF PRIMER CUP
(FOUND COVERING THE SENSITIVE END OF THE DETONATOR)

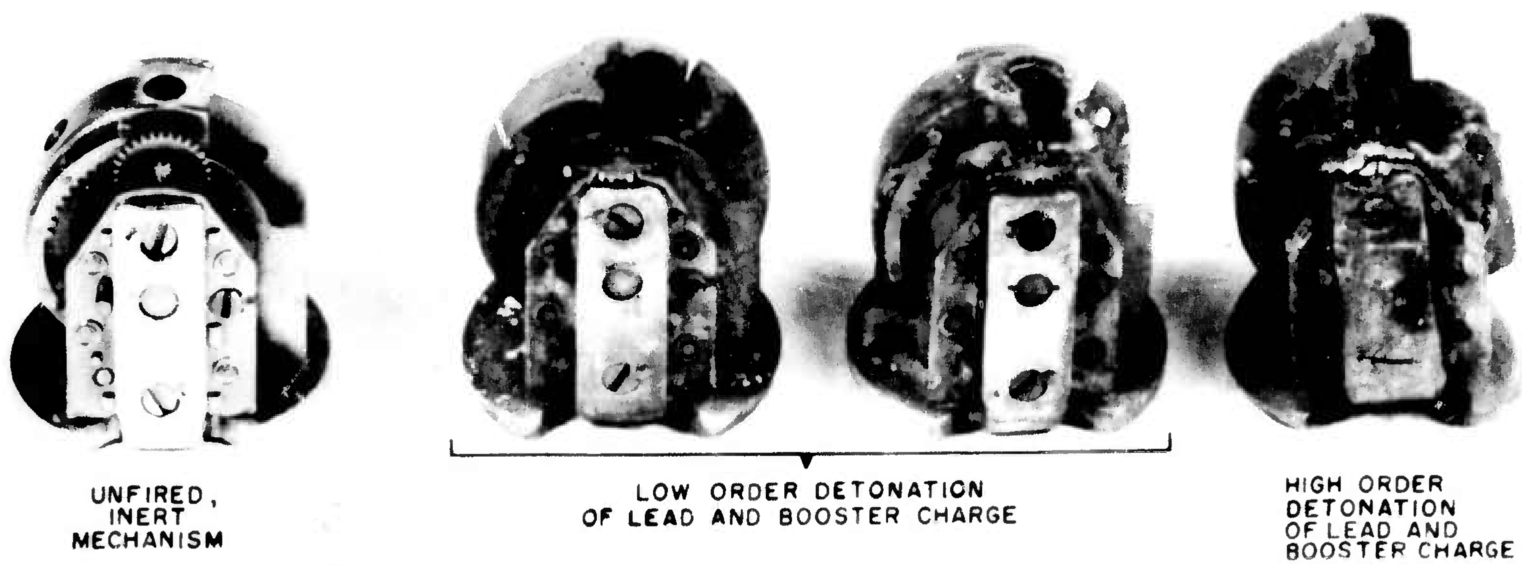
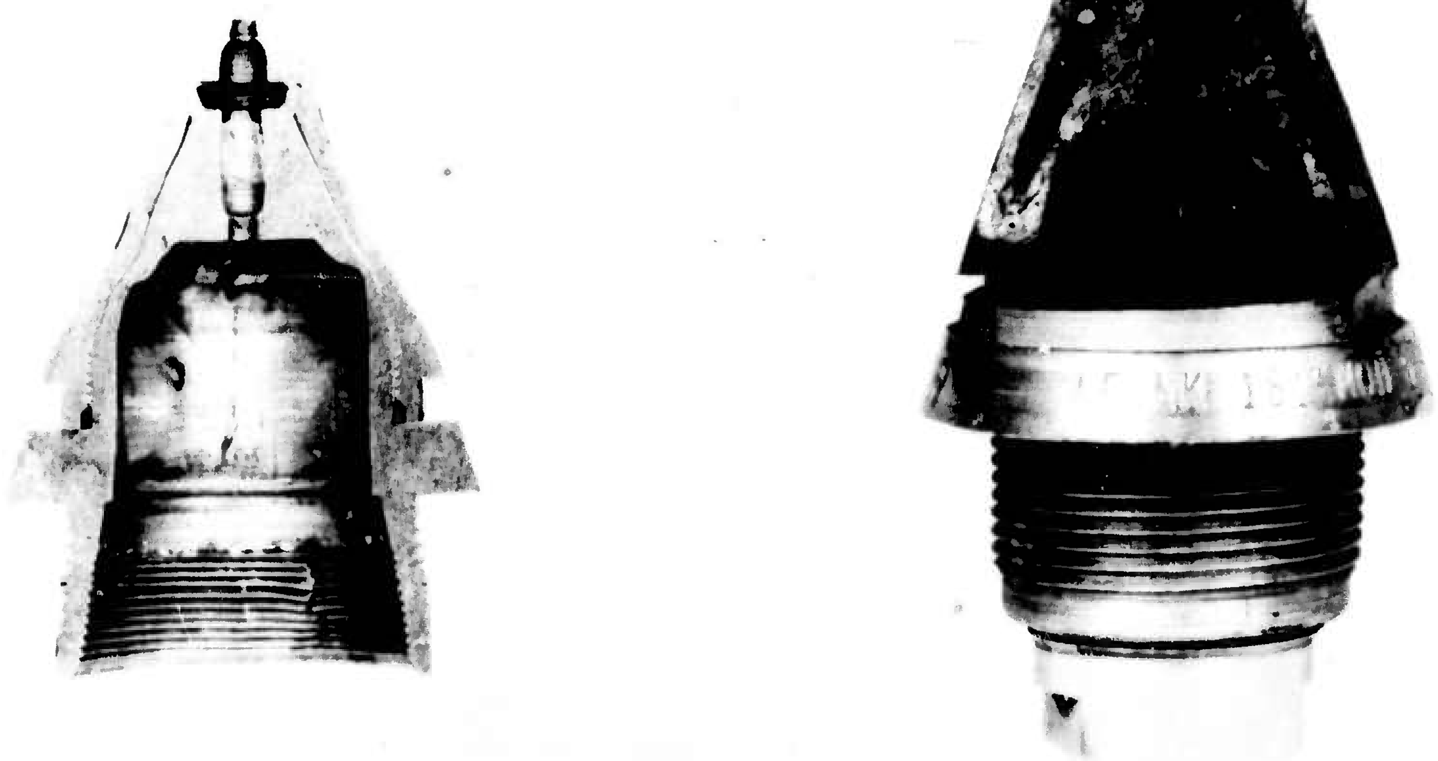


FIG. 10 DIFFERENCES OF DAMAGE TO NOTS 502A ARMING MECHANISM RESULTING FROM HIGH AND LOW ORDER DETONATION OF THE LEAD AND BOOSTER CHARGE



HIGH VELOCITY

LOW VELOCITY

FIG.11 EFFECTS OF HIGH AND LOW VELOCITY IMPACT

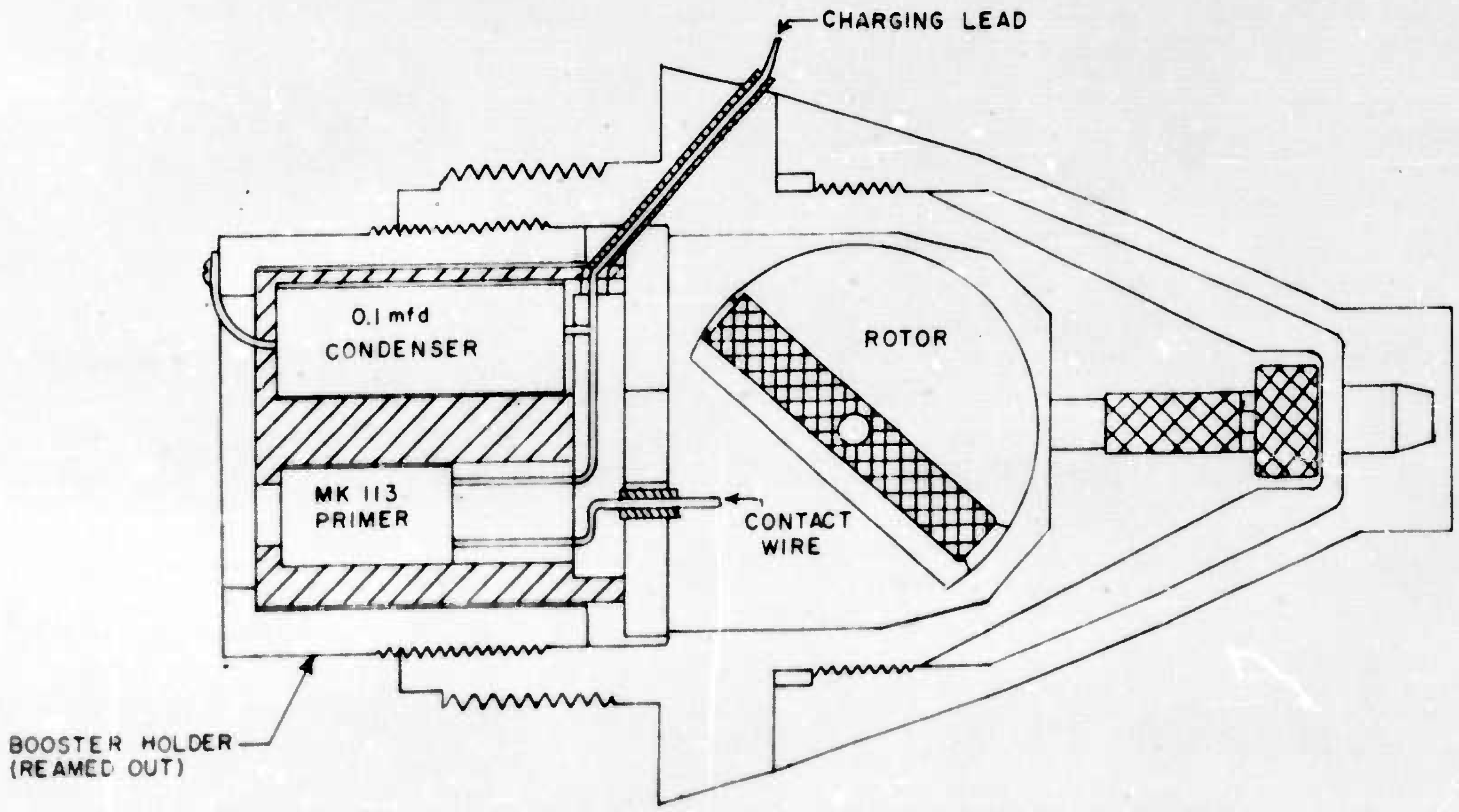


FIG. 12 INDICATING SYSTEM

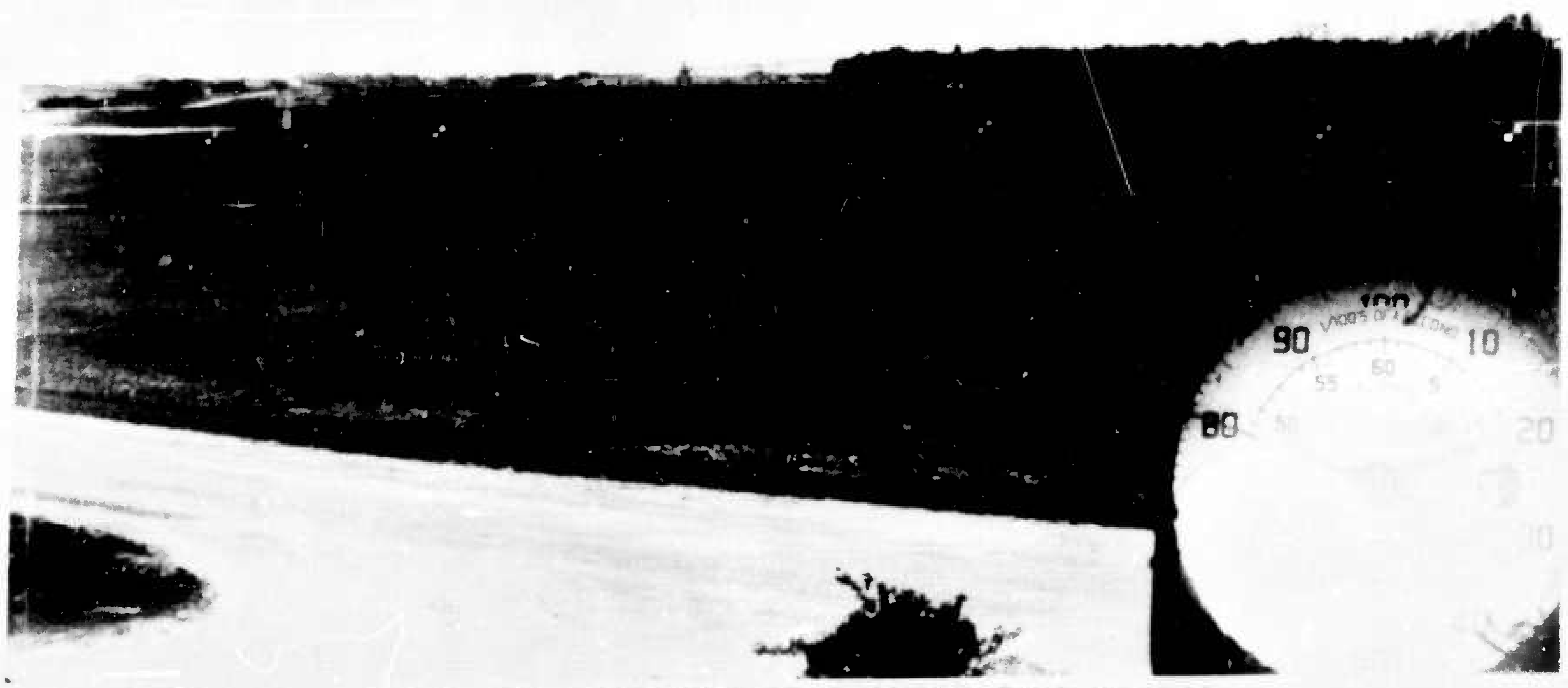
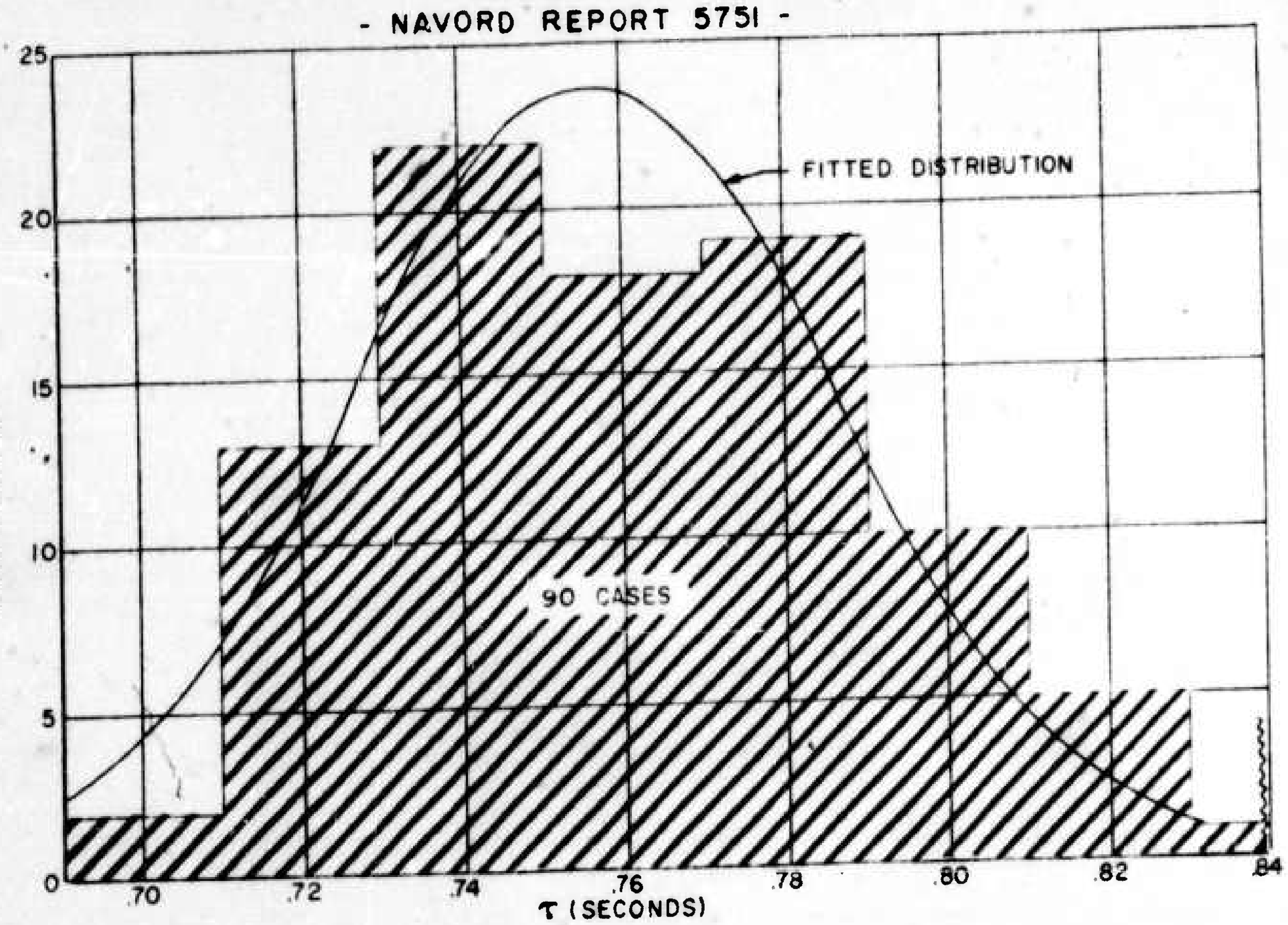
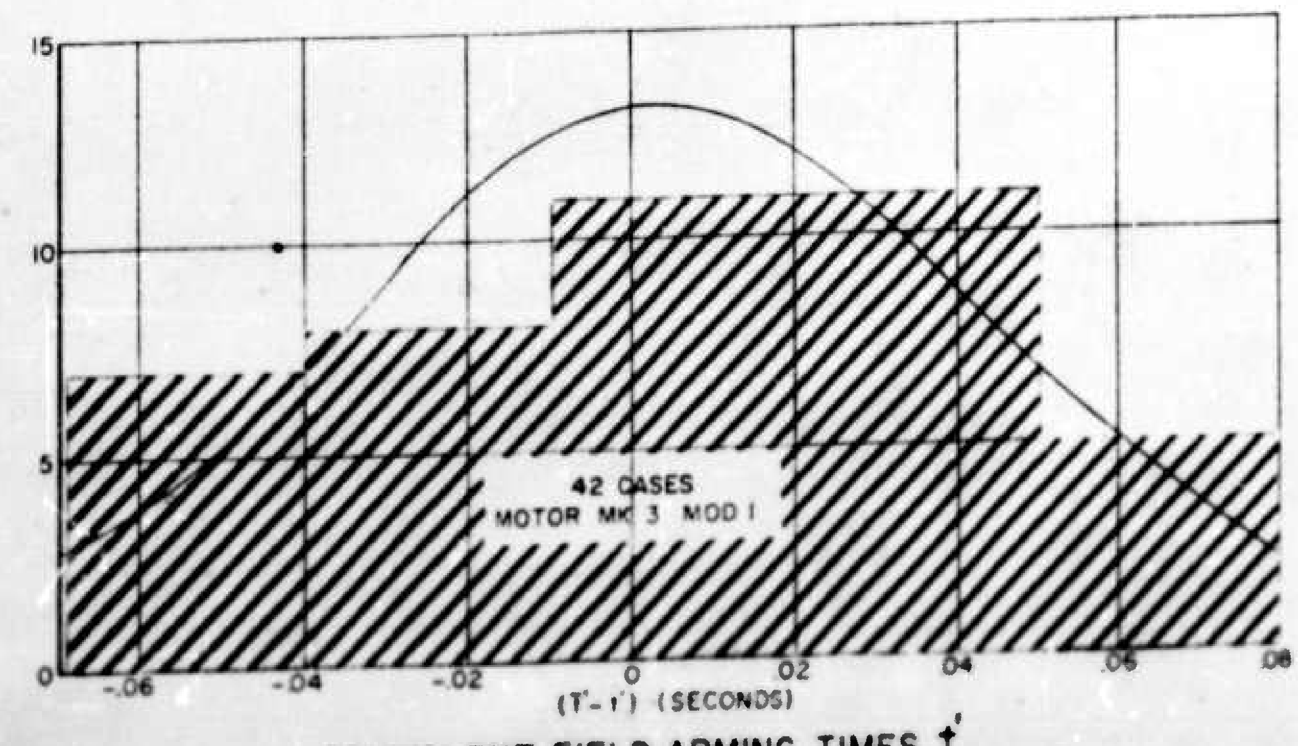


FIG. 13 ENLARGEMENT OF PHOTOGRAPHIC RECORD

CONFIDENTIAL



LABORATORY (CENTRIFUGE - 40 G) TIMES τ



EQUIVALENT FIELD ARMING TIMES τ'

FIG. 14

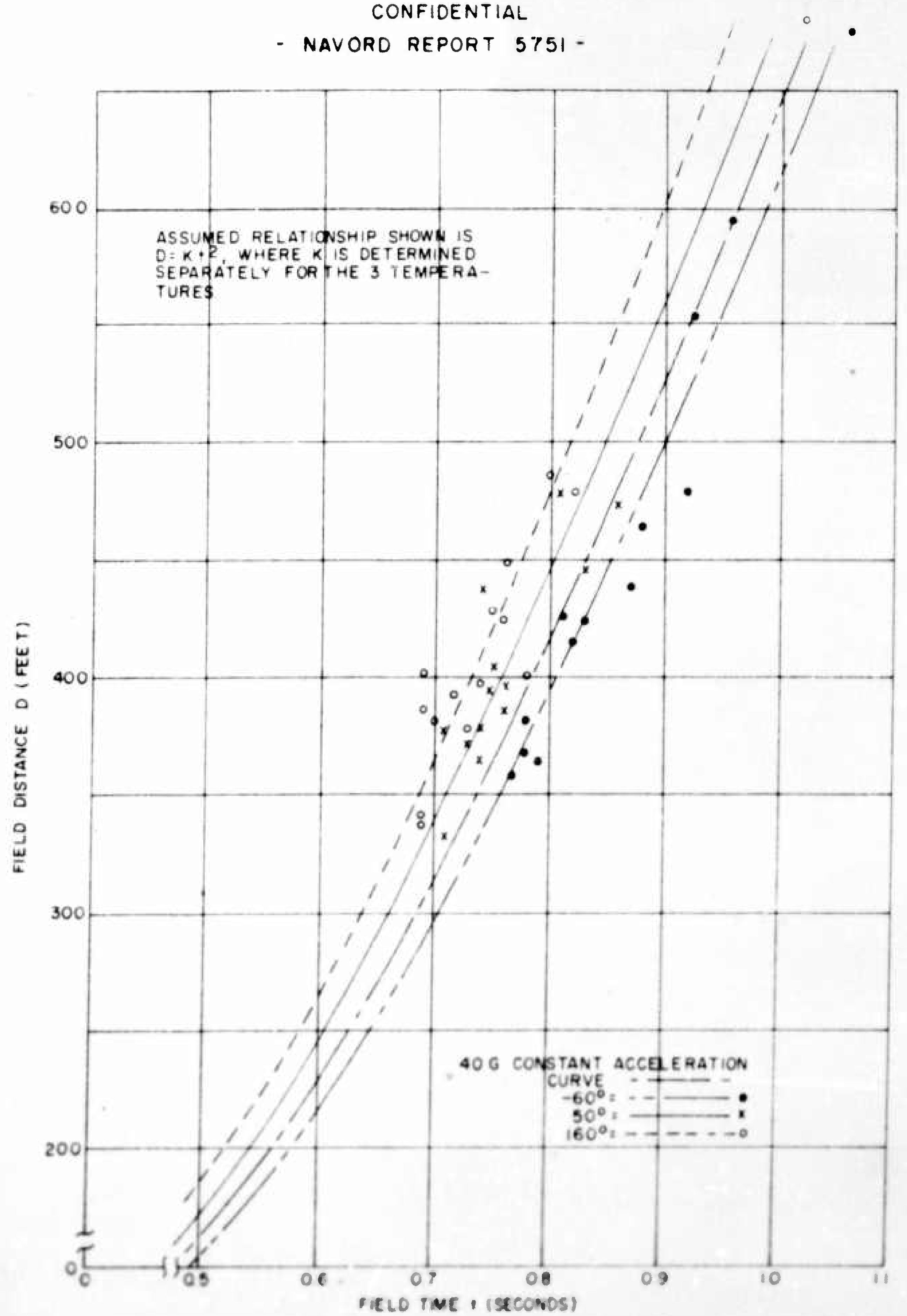
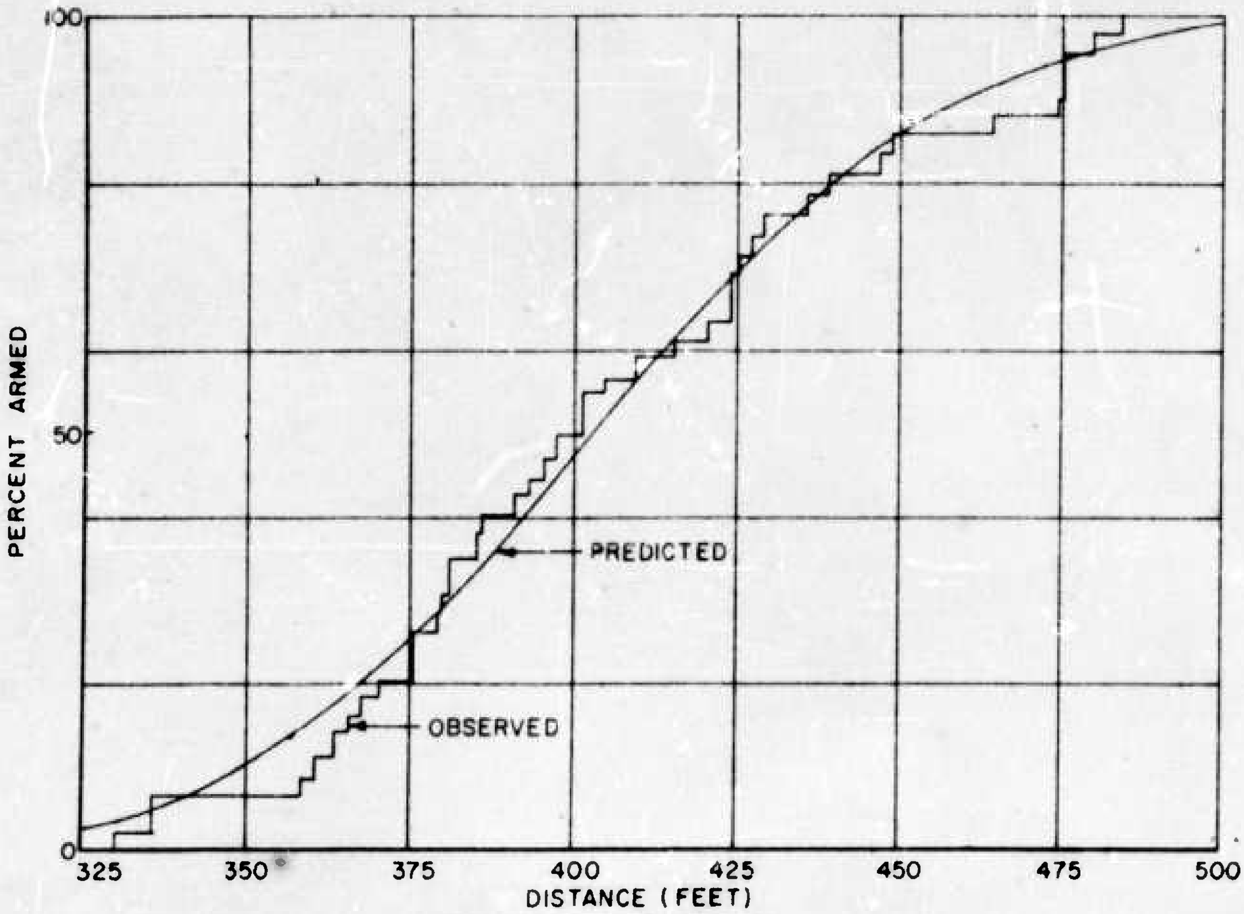
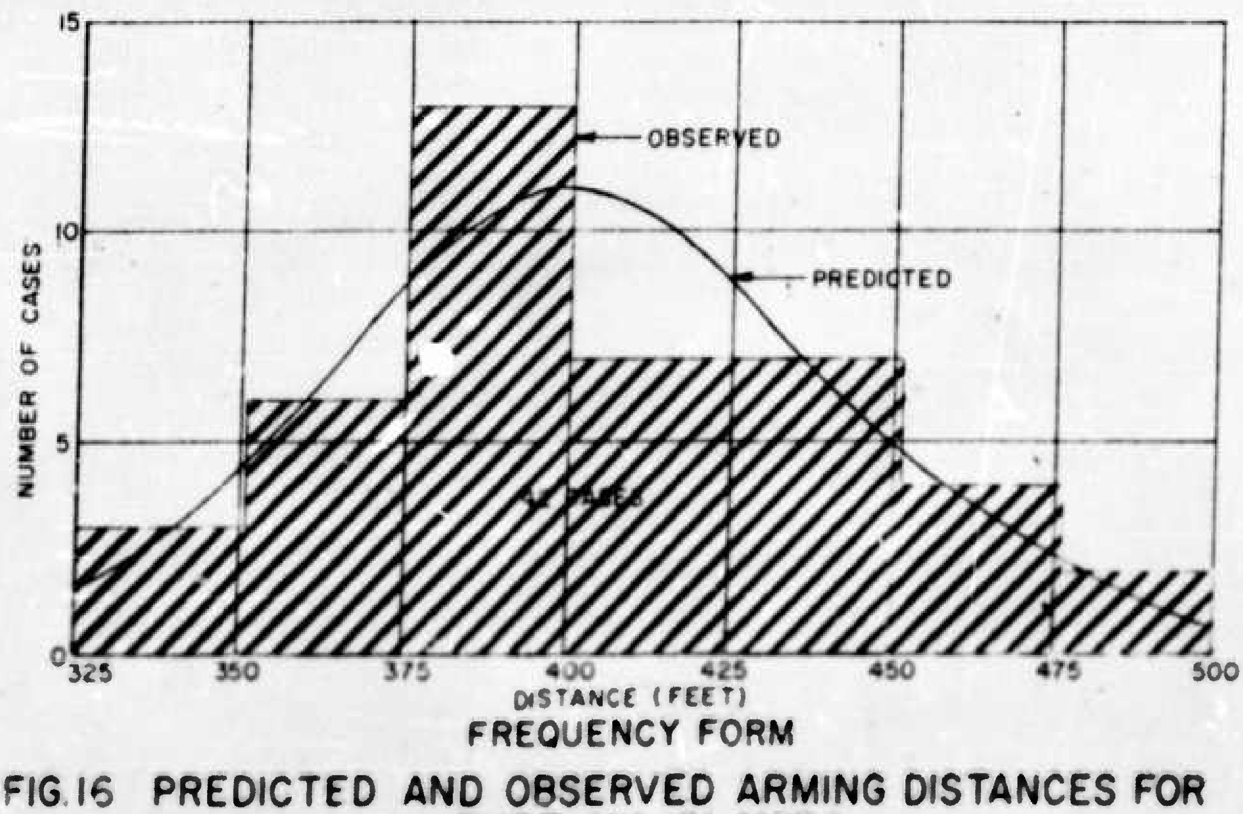


FIG. 15 TIME DISTANCE RELATIONSHIP FOR 2".75 ROCKET AT -60°F, 50°F & 160°F



CUMULATIVE FORM



FREQUENCY FORM

FIG. 16 PREDICTED AND OBSERVED ARMING DISTANCES FOR FUZE MK 181 MOD 1

TABLE 1

DATA USED IN COMPUTING LEAK RATES OF MK 181 FUZE BEFORE AND AFTER BEING SUBJECTED TO MIL-STD-304

	Prior to Mil-Std-304			Following Mil-Std-304		
Sample Number[1]	Initial Pressure in Microns[2]	Pressure Rise (in microns)[3]	Time of Pressure Rise (seconds)	Initial Pressure in Microns[2]	Pressure Rise (in microns)[3]	Time of Pressure Rise (seconds)
1	80	20	40	75	80	40
2	80	50	50	100	100	30
3	40	None	60	70	30	40
4	110	200	10	150	400	10
5	40	None	60	50	10	50
6	110	200	10	100	100	20
243	32	None	60	25	None	60
244	25	None	60	25	None	60
245	28	None	60	100	100	10
246	20	None	60	35	20	90
247	28	None	60	55	100	30
248	28	None	60	25	None	60
249	22	None	60	45	155	50
250	30	None	60	40	40	40

Notes:

1. Numbers 1-6 from Elgin Watch Company; numbers 243-250 from Bulova.
2. Pressure in bomb, see Figure 3, after vacuum pump was on for 90 seconds.
3. Pressure rise in bomb after system was closed to vacuum pump.
4. Volume of system = 200cc

Therefore $200 \times \frac{\Delta P}{760{,}000}$ = volume of air introduced to raise pressure of system from 0 microns to ΔP microns.

TABLE 2

INSPECTION RESULTS OF FUZE MK 181 (MADE BY ELGIN WATCH COMPANY) AFTER EXPOSURE TO ACCELERATED TEMPERATURE AND HUMIDITY TEST (INSPECTION MADE WITH 30X MICROSCOPE)

	FUZE NUMBER							
	1	2	3	4	5	6		
Leak Rate (x10^3 cc/sec) Before Conditioning	.13	.26	0	5.26	0	5.26		
Leak Rate (x10^3 cc/sec) After Conditioning	.53	.88	.20	10.5	.05	1.32		
Points of Observation of Arming Mechanism							**Total**	**Average**
1. Gear Train	2	3	1	1	2	1	10	1.7
2. Gear Rack	2	2	1	1	1	1	8	1.3
3. Arming Detent Shaft	1	2	1	1	1	1	7	1.2
4. Arming Detent Spring	2	3	1	1	1	1	9	1.5
5. Detent Locking Spring	2	4	2	1	1	1	11	1.8
6. Rotor Shaft	1	1	3	1	1	1	8	1.3
7. Setback Springs	1	3	1	1	1	1	8	1.3
8. Setback Weight and Guide	1	1	1	1	1	1	6	1.0
9. Aluminum Disc Holder	3	5	3	2	2	2	17	2.8
10. Clock Body (General)	1	1	4	1	4	1	12	2.0
TOTAL	16	25	18	11	15	11		
AVERAGE	1.6	2.5	1.8	1.1	1.5	1.1		

Legend: Following arbitrary scale used to estimate degree of corrosion

1 - No corrosion
2 - $>1<3$
3 - Comparatively moderate amount of corrosion
4 - $>3<5$
5 - Comparatively large amount of corrosion

TABLE 3

Conditions of Exposure of Primers and Detonators

	Primer	Detonator	Time Interval
1.	U*	U	72 hours
2.	P*	U	72 hours
3.	P	P	22 hours
4.	U	P	22 hours
5.	None	P	22 hours
6.	U	None	72 hours
7.	P	P	22 hours (Detonator) 72 hours (Primer) Both unmounted

*U - Unpunctured
P - Punctured

Composition of Primer and Detonator Mixtures

Primer

Component	Percent	Specification
Potassium Chlorate, Gr I, Class b	53 ±2	JAN-P-150
Antimony Sulfide, Gr I, Class b	17 ±1	JAN-A-159
Lead Thocyanate	25 ±1	JAN-L-65
Lead Azide	5 ±1	MIL-L-3055

Detonator

Component	Percent	Specification
Potassium Chlorate, Gr I, Class b	33.4 ±2	JAN-P-150
Antimony Sulfide, Gr I, Class a or b	33.3 ±2	JAN-A-159
Lead Azide	28.3 ±2	MIL-L-3055
Carborundum 150 grain	5.0 ±0.5	Commercial

TABLE 4

DROP TESTS ON FUZE MK 181
(Manufactured by Bulova Watch Company)
(Drop Weight - 50 lbs.)

Drop Height (feet)	Fires	Nonfires
4	4	6
5	8*	2
6	15**	0
7	5	0

* Low order detonation resulted in one of these samples
**Low order detonation resulted in two of these samples

(Manufactured by Elgin National Watch Co.)
(Drop Weight - 50 lbs.)

4	1	9
4.5	13*	2
5	12*	3
5.5	9	1
6	10*	0
8	14	1#
9	13	2#
10	11	4#

* Low order detonation resulted in one of these samples
# The primer was initiated but failed to initiate the detonator in all these drops. This was also observed in Bulova samples in other drop tests.

TABLE 5

SINGLE STAGE TEST SHOTS
LIVE-LOADED FUZE

Test No.	Target Material	Wt. (oz)	Impact Velocity (fps)	Results
1	Steel	13	176	High Order Detonation
2	Steel	13	125	Low Order Detonation
3	Steel	13	200	High Order Detonation
4	Steel	13	150	Low Order Detonation
5	Steel	13	176	High Order Detonation
6	Steel	13	187	High Order Detonation
7	Steel	13	125	High Order Detonation
8	Steel	13	100	High Order Detonation
9	Steel	13	79	No Detonation
10	Steel	13	94	No Detonation
11	Steel	13	100	High Order Detonation
12	Steel	13	77	No Detonation
13	Steel	13	91	High Order Detonation
14	Steel	13	73	No Detonation
15	Steel	13	134	High Order Detonation
16	Steel	13	270	High Order Detonation
17	Steel	13	129	High Order Detonation
18	Steel	13	100	No Detonation
19	Steel	13	126	High Order Detonation
20	Steel	13	112	No Detonation
21	Steel	13	128	High Order Detonation
22	Steel	13	124	High Order Detonation
23	Steel	13	120	High Order Detonation
24	Steel	13	138	High Order Detonation
25	Mag.	3	210	No Detonation
26	Mag.	3	518	No Detonation
27	Steel	13	136	High Order Detonation

TABLE 6

ARMING TIMES AND DISTANCES FOR THE FUZE MK 181 MOD 1

In this table T denotes the arming time measured by the manufacturer, τ denotes the arming time (laboratory) measured at NOL, t denotes the arming time measured in the field, and D denotes the arming distance measured in the field. (T and τ are constant 40g centrifuge times.) In part B, t' deonotes the equivalent field arming times which were computed from the corresponding value of D.

A. Motor Mk 1 Mod 3

1. -60° F

Fuze No.	T	τ	t	D	t'
A11	.72	.76	1.23	510	Not computed
A14	.73	.77	1.21	460	Not computed
A15	.76	.76	Hit ground		Not computed
A18	.74	.79	1.24	530	Not computed
A19	.74	.72	1.14	470	Not computed
47	.75	.73	1.48	623	Not computed
61	.75	.78	1.42	622	Not computed
88	.75	.76	1.31	543	Not computed
116	.74	.73	(no puff)		Not computed
120	.73	.76	(no puff)		Not computed
121	.69	.74	Hit ground		Not computed
123	.70	.73	1.29	557	Not computed
130	.76	.78	1.40	583	Not computed
131	.72	.81	1.25	494	Not computed
140	.79	.74	Hit ground		Not computed

2. 50° F

A5	.74	.76		375	Not computed
A6	.74	.77		800	Not computed
A9	.76	.79	0.86	415	Not computed
A13	.78	.77	0.96	480	Not computed
A17	.76	.79	0.78	395	Not computed
24	.73	.71	0.84	430	Not computed
59	.71	.72	0.96	520	Not computed
66	.73	.76		450	Not computed
77	.75	.73	(no puff)		Not computed
79	.74	.74	0.91	480	Not computed
93	.75	.77	0.88	455	Not computed
101	.79	.78	1.28	1020	Not computed
106	.74	.81	1.00	625	Not computed
107	.79	.73		415	Not computed
134	.76	.73	0.82	405	Not computed

TABLE 6 (Continued)

3. +160° F

Fuze No.	T	τ	t	D	t'
70	.74	.74		400	Not computed
84	.75	.76	Blew up		Not computed
85	.75	.83		495	Not computed
92	.74	.80		380	Not computed
100	.73	.78		410	Not computed
108	.75	.79		415	Not computed
115	.76	.79		465	Not computed
125	.77	.75		670	Not computed
127	.73	.81		475	Not computed

B. Motor Mk 3 Mod 1

1. -60° F

22*	.74	.77	1.06	675	1.049
36	.75	.77		381	.787
39	.75	.75	.82	415	.821
51	.70	.72	.81	425	.831
56	.75	.80	Blew up		
57	.74	.72	.88	464	.870
67	.72	.72	.78	381	.787
95*	.73	.71		1200	1.400
109	.77	.77	.92	479	.883
110	.76	.72	.77	359	.764
111	.77	.73	.79	363	.769
118	.75	.74	.78	367	.773
126*	.73	.76	.96	602	.990
129	.80	.72	No puff		
135	.75	.78	.83	424	.831
136*	.76	.71	1.02	684	1.055
137	.77	.82	.87	439	.846

2. 50° F

15	.73	.80	.73	371	.733
40	.71	.71	.75	393	.754
49	.73	.76	.81	475	.829
76	.71	.72	.75	404	.764
82	.70	.71	.71	331	.692
90	.73	.74	.74	366	.727
91	.74	.74	.86	474	.828
99*	.75	.76	.51	175	.503
102	.71	.77	.76	396	.757
103	.73	.76	.75	386	.747
114	.75	.73	No puff		

TABLE 6 (Continued)

Fuze No.	T	τ	t	D	t'
117	.77	.75		409	.770
119	.78	.82	.74	436	.794
122	.67	.78	.74	376	.737
128	.72	.69	.71	376	.738
133	.75	.80	.83	447	.804
138	.75	.76	No puff		
3.	+160° F				
19	.75	.75		421	.754
41	.74	.76	.76	449	.779
45	.73	.74	.69	385	.721
53	.74	.78	.76	424	.757
54	.74	.78	.72	391	.726
71	.73	.73	.80	484	.809
72	.72	.74	.73	379	.715
73	.73	.74	.69	337	.674
78	.73	.70	.69	401	.735
83	.73	.74		428	.761
104	.75	.77		361	.698
105	.80	.77	.70	380	.716
112	.75	.74	.75	427	.815
113	.75	.74	.78	400	.735
124	.79	.77	.82	475	.800
132	.72	.80	.74	397	.732
139	.78	.75	.69	337	.674

*Data omitted from the analysis. The long and short times lie outside the expected time interval and indicate either (1) malfunctioning of instrumentation or (2) a non-representative timing device.

TABLE 7

TIMES OBTAINED ON 19 MECHANISMS AT NOTS ON CENTRIFUGE AT 40G CONSTANT ACCEL.

(Times in thousandths of sec)

Mechanism	1st	2nd	3rd	4th	5th	Mean Time
1	807	752	752	747	749	761
2	770	769	769	750	751	762
3	823	825	816	823	815	820
4	806	798	804	799	798	801
5	839	801	803	816	801	812
6	724	728	721	725	719	723
7	780	781	780	780	780	780
8	829	808	801	803	803	809
9	758	759	762	760	762	760
10	824	796	791	795	803	802
11	799	798	795	790	790	794
12	780	773	780	775	775	777
13	790	765	772	775	766	774
14	800	758	755	756	760	766
15	786	781	780	779	789	783
16	841	823	820	821	815	824
17	783	780	780	781	799	785
18	748	747	746	762	769	754
19	764	772	766	767	758	765
$\bar{X}$	792					782
S	032					026

DISTRIBUTION

	Copies
Commander, U. S. Naval Ordnance Test Station Inyokern, China Lake, California	2
Chief, Bureau of Ordnance (ReW3) Washington 25, D.C.	1
Commanding Officer, Picatinny Arsenal Dover, New Jersey	2
Commander, U. S. Naval Proving Ground Dahlgren, Virginia	1
Commander, U. S. Naval Ordnance Laboratory Corona, California (Code 55)	2
ASTIA (TIPDR) Arlington Hall Station Arlington 12, Va.	5